PRESTRESSED CONCRETE INSTITUTE

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JOURNAL

OF THE PRESTRESSED CONCRETE INSTITUTE

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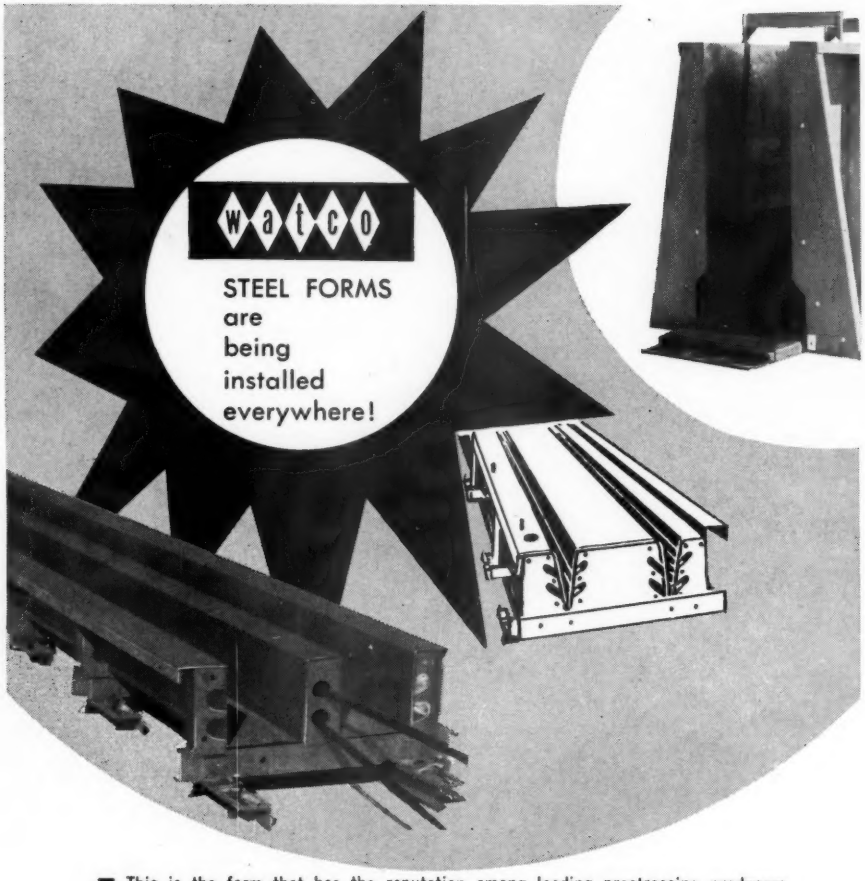

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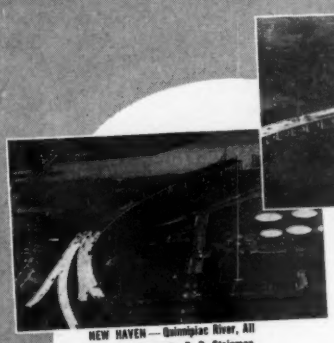

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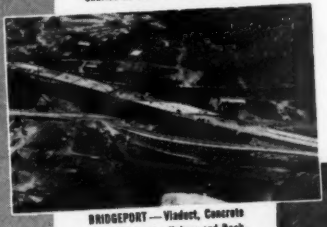

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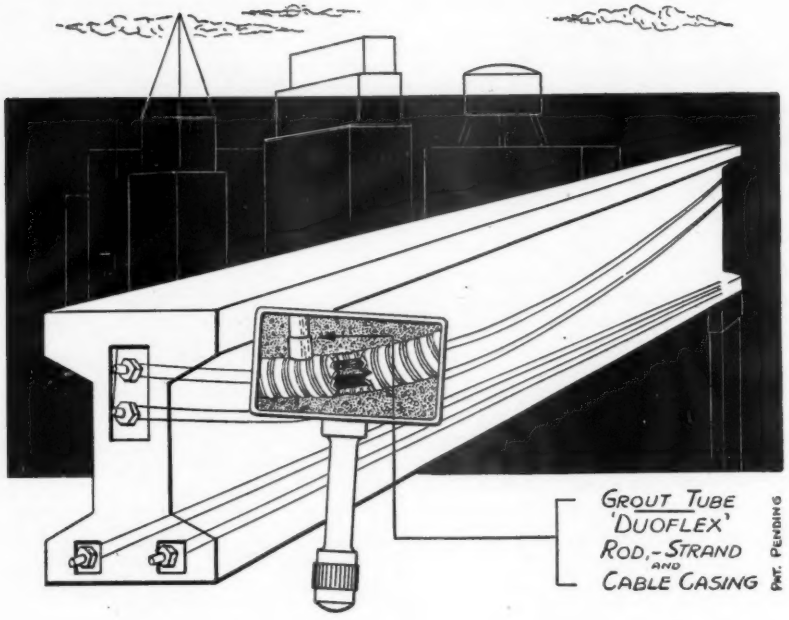

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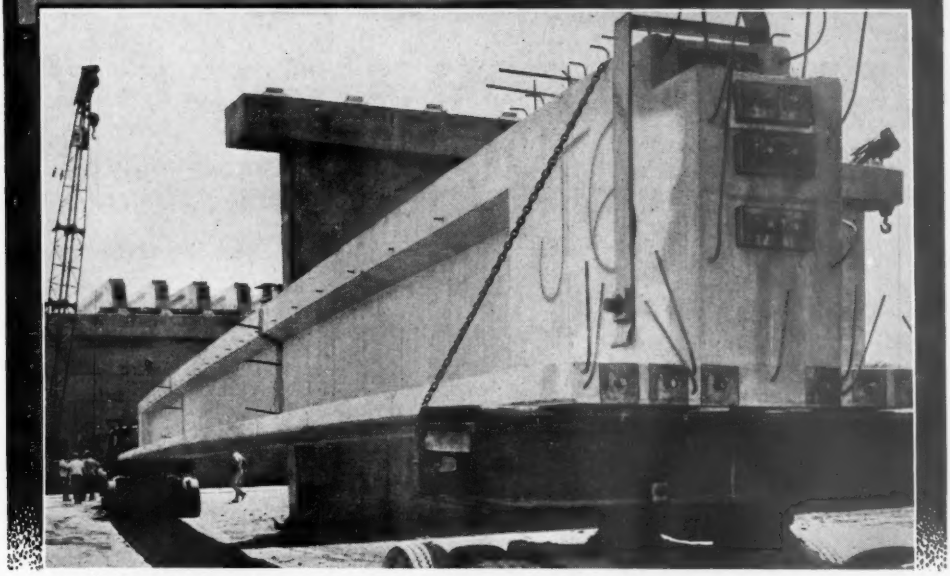

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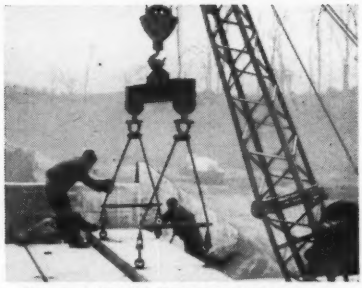

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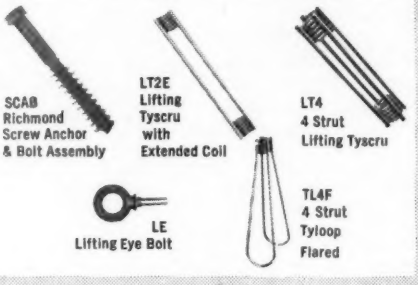
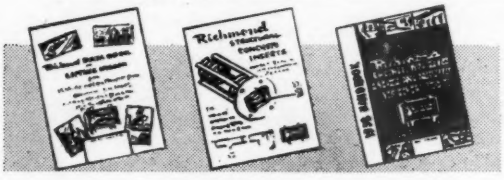


The Richmond Data Book on Lifting Inserts and the new Richmond Bulletin on Structural Concrete Inserts give complete information about these and the many other Richmond Inserts specifically designed for safety and economy. Send for them — and for the current Richmond Handbook describing the full line of more than 400 Richmond-engineered products for the concrete construction industry. They are free for the asking. Write to:



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What is P. C. I.?

By J. REX FARRIOR, JR.
Legal Counselor for P. C. I.
Tampa, Florida

P.C.I. is legally known as Prestressed Concrete Institute, Inc., a corporation not for profit organized and existing under the statutes of Florida, Chapter 617. The Institute is legally recognized as a scientific, charitable and benevolent association.

The original charter was approved by the Circuit Court at Tampa, Florida, on June 18, 1954. Officially, the object of the Institute is the formation of an association of manufacturers of prestressed concrete and of persons and companies in allied or related industries for the mutual exchange of information and ideas; and generally to do anything beneficial for its members and the prestressing business which does not violate the laws of Florida or the United States.

The charter provides for seven classes of members: Active, for prestressed manufacturers; Associate, for related businesses; Professional, for architects and engineers; Affiliate, for supervisory and technical employees, non-graduate; Junior, for architects and engineers in training; Student, for students enrolled in accredited architectural and engineering colleges, and Honorary, for such persons as the Board of Directors may wish to honor.

From a tax standpoint, the Institute enjoys an enviable position. Being a valid non-profit corporation, it is not required to pay any tax on its receipts, and therefore 100 per cent of its income can be devoted to research and other useful projects.

Fortunately, also each member's dues and contributions are completely deductible by the member for income tax purposes.

Both tax factors therefore guarantee to the Institute's members more than full value for each dollar invested.

JOURNAL

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From the editor. . .

We are truly proud of our technical JOURNAL, of its ever-increasing high educational value and its growing demand around the world. Each issue furnishes the equivalent of several short courses. And this copy gives us added pride because of two new "firsts."

It carries the Underwriters' Laboratories' report of our first fire test, establishing for the first time an official fire rating, dispelling all doubt of the efficacy of prestressed concrete against fire, and sets the pattern to guide our additional tests now being planned.

Another "first" of magnitude — our STANDARDS FOR PRESTRESSED CONCRETE PLANTS, a model promising certified plants, a boon to the industry and public confidence, a PCI citadel of guidance for public authorities.

Then on to our own grand "Mike" Dubois telling the U. S. story at the Berlin FIP Congress. Next, the fascinating picture story of prestressing in Scandinavia by their outstanding engineers Ostenfeld and Kalhauge. What an inspiring tour with these two articles! Back home again, the Normandy Elementary School — and finally "Readers' Comment," where we pause for meditation. We now let you take the podium.

The **JOURNAL** is published quarterly by the **PRESTRESSED CONCRETE INSTITUTE, INC.**, 425 N. E. Fifth Street, Boca Raton, Florida. **TECHNICAL EDITOR:** Dr. A. M. Ozell, University of Florida, Gainesville, Florida. **ASSOCIATE EDITOR:** Douglas P. Cone, P. O. Box 11476, Tampa, Florida. **ADVERTISING, SUBSCRIPTION** and **PUBLICATION OFFICE:** 3132 N. E. Ninth Street, Fort Lauderdale, Florida. **DISTRIBUTION:** Available without cost to all members of the Prestressed Concrete Institute. **SUBSCRIPTION PRICES:** $6.00 per year for four issues. Single copy price: $2.00. For subscriptions outside the continental United States, add 20% to cover handling and mailing. Editorial contributions to the **JOURNAL** are welcomed, but publication cannot be guaranteed. All manuscripts should be submitted in duplicate and will be reviewed by the Technical Editor prior to publication. Advertisements of products, services and materials allied to the prestressed concrete industry are acceptable. Inquiries concerning advertising, and subscriptions should be directed to the Publication Office.

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PRESTRESSED CONCRETE INSTITUTE

Committee on Fire Resistance Rating

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The Underwriters' Laboratories, Inc., report R 4123-1 of May 12, 1958 establishes for the first time a fire rating for prestressed concrete construction based on standard fire test specifications. Recognition in this form is of prime importance because at once it dispels all doubt as to the stability that can be provided by prestressed concrete in building construction against the ravages of fire.

Of perhaps greater importance is the information and knowledge that is being gleaned from the data obtained during and after the test. This is being used as a guide in setting up a continuing program calculated to develop more practical results from several types of members.

The particular design and construction submitted by the Prestressed Concrete Institute for the initial test was selected with these points in mind. While it was recognized that all details of design would not in every case lend themselves to the most economical fabricating practices, they were deemed necessary in the interest of developing ultimately the most useful results in an orderly fashion.

The requirement of a 3" non-structural topping should in no sense be construed as a reflection on the behavior of prestressed concrete under standard fire test conditions. The stability demonstrated during the prescribed two hours of exposure and for one hundred hours after exposure proves that the prestressed construction tested has the required structural strength. A fire resistant structure must also provide protection against passage of flame and dangerous heat transmission. This is the function of the 3" concrete topping. Other materials having the same proven insulating capacity could be substituted. These factors, including the use of the concrete topping to make a composite structure, and others pertinent to the use of prestressed concrete members in building construction are on the agenda for further investigation and test.

This report is published as a service to the membership of the Prestressed Concrete Institute who sponsored the work and to others interested in the behavior of prestressed concrete when under exposure of fire.

July 31, 1958

Approved
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Retardant 4123-1
Application No. 57C7689A
May 12, 1958

*REPORT

on

FLOOR OR ROOF CONSTRUCTION CONSISTING OF PRESTRESSED CONCRETE DOUBLE TEE SLABS

Prestressed Concrete Institute
Boca Raton, Florida

*Reprints can be purchased from the Publication Office, Prestressed Concrete Institute, 3132 N.E. Ninth St., Fort Lauderdale, Fla. @ $2.00 per copy prepaid (Members $1.00 per copy prepaid)

DESCRIPTION

GENERAL:

Prestressed concrete floor and roof slabs are of many designs. The subject of this report is a precast prestressed concrete double tee slab of the design shown on Figs. 1, 2, and 2A used to form a roof or floor test assembly as shown on Figs. 4 and 5.

To avoid delay for curing purposes, it was planned to conduct this investigation to determine the performance of the slabs under design load without a concrete topping.

THE INVESTIGATION

The purpose of this investigation was to establish a fire-retardant classification for the floor or roof assembly, consisting of double tee prestressed slabs when tested for load-bearing capacity, in accordance with Underwriters' Laboratories, Inc.'s Standard for Fire Tests of Building Construction and Materials, UL263 (NFPA 251; ASTM E119). The necessary topping to satisfy heat transmission properties of the assembly was to be computed on the basis of available fire test data. The fire test was supplemented by other tests and examinations to determine the physical properties of the material used and the practicability of handling, shipping, and installing.

EXAMINATION AND TEST RECORD

The materials used in the assembly are described below in the order of use.

Steel Beams — The beams used to support the ends of the concrete units were 8-in. wide, 27-lb flange, structural steel members on the top of which rested 3-in. wide by 1½-in. thick steel bars. (See Fig. 1.)

Precast-Prestressed Concrete Double Tee Slabs — The slabs were manufactured at a local plant selected by the submittor, and were of the shape and design as shown on Figs. 1, 2, and 2A.

The slabs were of the draped-strand design wherein the strands are lower at the center of the T-slabs than at the ends as shown on Fig. 1. The two strands in each tee were held down at the middle of their span length by a hold-down device shown on Fig. 3. The ends of the strands were held by means of gauges to the heights as shown on Fig. 1 until the concrete had reached the required strength at which time the gauges were removed and the strand wires cut. Each strand was 5/16 in. diameter and contained seven wires.

The concrete was a 1-in. maximum slump mix using sand, limestone, and high early strength cement. Compressive strength tests of representative 6- by 12-in. cylinders made of the mix as used in the slabs and steam cured in a similar manner developed a minimum of 6101 psi, a maximum of 7587 psi, and an average of 7142 psi at 28 days.

Data, such as tension applied to strands, mix, and strength of concrete when the strands were cut and other details concerning the manufacture of the units, are on file at Underwriters' Laboratories, Inc. for use in connection with future inspections.

ERECTION OF TEST ASSEMBLY:

The precast-prestressed double tee slabs were provided in width so that three units completely filled the test furnace allowing 3-in. minimum bearing on supports at the ends. The space between the slabs and the furnace frame was grouted to provide restraint, on all edges. The joints between units were filled with rock wool so as to prevent the passage of smoke and flame.

The appearance of the test assembly after erection in the furnace is shown on Figs. 4 and 5.

FIRE ENDURANCE TEST:

The test was conducted in accordance with the Standard for Fire Tests of Building Construction and Materials of Underwriters' Laboratories, Inc.

DESCRIPTION OF SAMPLE

The fire test assembly was erected as described in "Erection of Test Assembly," and as shown on Figs. 1, 4, and 5.

At the time of the fire test, the units had aged 111 days. A relative humidity of

77 per cent was determined from an electrical moisture-sensing element located 2½-in. above the bottom of a tee, in a representative sample. Surface relative humidity, measured in a similar fashion, was approximately 42 per cent.

METHOD

The load applied to the test assembly was arranged to provide a uniformly distributed load of 40 psf. This load was specified by the submittor, and calculated on the basis of design formulas as shown in detail on Figs. 2 and 2A. The design, method, and calculations are shown, since a nationally recognized Standard has not been developed for prestressed concrete.

Twenty hours after the floor was loaded, the furnace fire was started exposing the assembly to flames of controlled extent and severity in accordance with the Standard Time-Temperature Curve.

The temperatures in the furnace chamber were measured with 12 thermocouples symmetrically located as shown on Fig. 5.

The unexposed floor surface temperatures were measured by thermocouples, Nos. 1 through 9, located as shown on Fig. 7. Thermocouple Nos. 10, 11, 12, and 13, as shown on Fig. 7, were peened into the top ends of the hold-down devices and covered with standard pads. Thermocouple Nos. 14 and 15 were attached to the lifting hooks, placed in each tee at the end of the slabs. See Fig. 4 for a general view showing lifting hooks and thermocouple locations.

The temperatures of the prestressing strands were measured by means of thermocouples affixed to the strands at depths of cover of 2, 2½, and 3 in., provided by the concrete.

The deflection of the floor was observed through a surveyor's level, placed on one side of the furnace, and sighted on five vertical targets, each graduated in 0.10 in. and located as shown on Figs. 4 and 7.

Throughout the test, observations were made of the character of the fire, its control, the condition of the exposed surfaces, and all developments pertinent to the performance of the assembly with reference to stability for use as a fire retardant.

RESULTS

Observation During Application of Load — A maximum deflection of 0.07 in. occurred in the middle slab as indicated by Targets 2, 4, and 5 as a result of the load applied. No additional deflection occurred prior to the start of the fire exposure.

Character and Distribution of the Fire — The furnace fire was smoky and somewhat under the Time-Temperature Curve as shown on Fig. 6.

Observation of the Unexposed Surface — Approximately 5 minutes after the start of the fire exposure a crack parallel to, and 18 in. from, the west furnace frame developed in the west slab. At about 39 minutes, a similar crack 25 in. from the east furnace frame occurred in the east slab.

By 45 minutes a crack developed in the south end of the middle slab, and by 95 minutes corner cracks were apparent in the east and west slabs. The cracks continued to open throughout the test reaching a maximum of ⅛ in. by test termination.

Moisture appeared on the surface by 15 minutes and remained until approximately 95 minutes, when the surface appeared dry.

Observation of the Exposed Surface — Approximately 8 minutes after the start of the test a 6-in. diameter section at the joint between the middle and east slabs spalled to a depth of ¼ in. Starting at 12 minutes, a 6-in. long corner section of the second tee from the west edge spalled to a depth of approximately ¾ in., and spalling in the other tees continued until 20 minutes. No further spalling occurred. The maximum depth of spall appeared to be 1 in., exposing the wire fabric in one tee but no prestressing strands were exposed.

At about 47 minutes, a 2½-ft. long crack was noted in the soffit of the third tee from the west edge at the approximate centerline.

By 58 minutes hairline tension cracks, spaced about 12-14 in. apart began developing in all tees. By 76 minutes the tension cracks appeared open 1/16 in. and by 87 minutes

the cracks extended from the tee soffit to the underside of the slab and were open ⅛ in. As the test progressed, additional tension cracks formed and gradually opened. The test was terminated at 2 hours, 1 minute at the request of the submittor's representative at which time the maximum crack opening was about ¼ in.

The hose stream and double live load tests were not conducted.

Deflection of the Floor — A maximum downward deflection of 4.33 in. at the center of the middle slab was noted at the end of the fire test as indicated by Target 2, and as shown in the following table. The slab continued to deflect until 24 hours after the furnace fire was extinguished at which time equilibrium seemed to be reached.

DEFLECTION

	Inches Target				
Time	1	2	3	4	5
0	0.02	0.07	0.02	0.07	0.07
5 minutes	0.20	0.44	0.12	0.36	0.44
10 minutes	0.18	0.50	0.09	0.36	0.49
15 minutes	0.03	0.68	0.23	0.10	1.10
30 minutes	0.33	1.09	0.34	0.57	1.00
45 minutes	0.20	1.38	0.45	0.66	1.25
60 minutes	0.26	1.98	1.04	0.86	1.70
75 minutes	0.28	2.58	1.54	1.21	2.17
90 minutes	0.48	3.18	1.99	1.46	2.60
105 minutes	0.73	3.88	2.54	1.81	3.05
121 minutes	0.93	4.33	2.64	2.06	3.30
Furnace fire extinguished at 121 minutes.					
DEFLECTION — AFTER FURNACE FIRE EXTINGUISHED					
20 minutes	1.16	4.73	2.92	2.29	3.53
1 hour		5.16			
4 hours		5.38			
24 Hours	1.68	5.88	3.42	3.29	4.15
96 hours	1.70	5.86	3.42	3.30	4.16
DEFLECTION — AFTER LIVE LOAD REMOVED					
100 hours	1.93	5.20	3.27	2.92	4.03

Temperature of the Unexposed Surface — The initial average temperature of the unexposed surface was 68 F; therefore, the average limiting temperature was 318 F, and the maximum limiting individual temperature was 393 F. The average limiting temperature was reached by thermocouple No. 3 at 22 minutes as shown on Fig. 7.

Temperature of the Prestressing Strands — Temperature data of the prestressing strands were recorded and shown on Fig. 8.

OBSERVATIONS AFTER TEST:

After the sample had cooled and the load removed, it was noted that the middle slab had regained 0.60 in. from its maximum deflection, the west slab had further deflected 0.23 in., and the east slab regained 0.15 in.

From a straight edge placed on the centerline across the three slabs, as shown in Fig. 10 measurements were taken at the edges near the joints between adjacent slabs, and are tabulated below.

Joint, In.		Joint, In.	
West	Middle	Middle	East
3-½	4-⅛	6	4-⅞

The unexposed surface of the west and east slabs had cracks 18 in. and 25 in. respectively, from the furnace side frames throughout their entire length. Each slab had diagonal cracks across their ends. The cracks were open to a maximum of ⅛ in.

The exposed surface of the assembly was craze cracked with the tees spalled at

the corners. The depth of the spalled areas varied to a maximum of about 2 in., which occurred in the second tee from the left as shown on Fig. 9.

Some reinforcing wire fabric was exposed in the slab section and in the spalled areas in the tee section as shown on Fig. 9.

The tension cracks were open to a maximum of ¼ in. as shown on Fig. 9.

The double tee slabs were removed from the furnace frame by lifting them out in the same manner as was used in the initial installation. The units maintained their general distorted shape (see Fig. 10), during a period of a month stored outside.

RECORD IN SERVICE

Precast-prestressed double tee floor or roof units are relatively new, and to date no reports of field service have been received and no details of fire service are available.

Supervision of Product by Underwriters' Laboratories, Inc.:

Precast-prestressed double tee units, conforming to the cross-sectional dimensions, design, and properties given herein and on file will be listed under the Label Service as "Precast Concrete Units," Guide No. 40 U18.16C for use with the specified minimum thickness of concrete top fill.

CONCLUSIONS

FIRE-RETARDANT PROPERTIES:

Floor and roof assemblies, constructed of precast-prestressed double tees of the design and cross-sectional dimensions as described herein, when used with a poured-in-place concrete top fill 3 in. thick, will afford 2-hour protection against passage of flame and dangerous heat transmission, provided:

1. The assemblies are restrained at the edges.
2. Bearing on the supports is 3 in. minimum.
3. The concrete topping is not considered as a structural element of the assembly.

The assembly, as tested without concrete topping, carried the live load for 2 hours, 1 minute during fire exposure and continued to carry the live load until removed after approximately 100 hours had elapsed.

Previous published test results of monolithic reinforced concrete floors shows that 3 in. of a normal concrete topping in conjunction with the slabs tested, will provide 2-hour protection for the assembly against passage of flame and dangerous heat transmission.

The above limitations were the conditions under which the assembly was tested.

DESIGN AND CONSTRUCTION:

Precast-prestressed concrete members utilized in floor or roof constructions are of varied design. Only the units of the design and cross-sectional dimensions, and installed as given herein can be evaluated from the test information contained in this report.

PRACTICABILITY:

The precast-prestressed concrete double tee units of the design as given herein can be readily erected in the field by workmen familiar with such installations. The placing of the concrete top fill will require the usual supervision for such construction.

STRENGTH:

The precast-prestressed concrete units of the design tested, without normal concrete topping, showed stability under standard fire test conditions for 2 hours.

When the load-carrying capacity is derived from the design formulas as shown on Figs. 2 and 2A, the load-carrying capacity should not utilize the concrete top fill as a structural element until fire tests of the composite assembly evaluate it.

UNIFORMITY:

The precast-prestressed concrete units, as described herein, are of uniform character within limitations established under the Inspection Service contemplated.

CONFORMITY:

This construction was tested in accordance with the Standard for Fire Tests of Building Construction and Materials of Underwriters' Laboratories, Inc., with the deviation from the Standard on the limiting aspects of heat transmission waived. Heat transmission properties, however, comply with the Standard when 3 in. of concrete topping is placed on the units at the job site as based on prior test data.

RECOMMENDATION

TO THE FIRE COUNCIL OF UNDERWRITERS' LABORATORIES, INC.:

We recommend promulgation of listing cards in the forms presented below whenever a manufacturer of precast-prestressed concrete double tee units demonstrates that his product conforms with the design, dimensions, and specifications as set forth for the product used in this test.

Guide No. 40 U18.16C. Date File
Precast Concrete Units.

_____(Manufacturer, City, Zone, State).
For Floor, Roof, and Ceiling Design No._____ — 2 Hr.

_____(Street Address).
Label Service — See General Information Card of above guide number.
See Guide No. 40 U18 for illustration of design numbers and fire-retardant classification.

* * * * * *

Precast Concrete Units.
Guide No. 40 U18.16C. Date

This classification includes precast concrete slabs and planks, hollow or solid, for use in bearing walls and floor or roof assemblies of the kind indicated in the following individual listings. The units are cast at the plant and consist of portland cement and fine and coarse natural or processed aggregates. The reinforcement may be wire fabric, deformed bars and/or high tensile strength wire strand. The fire-retardant classifications given in the following individual listings are based on installation methods shown in the indicated design sketches (shown under Guide No. 40 U18).

The label of Underwrters' Laboratories, Inc. attached to the product is evidence that such product has been produced under the Factory Inspection and Label Service Program.

The Label Service of Underwriters' Laboratories, Inc. includes inspection of concrete mix and strength, dimensions of unit, and location and type of reinforcement for compliance with specifications established on the basis of the product used in the fire test of individual structures.

Tests by:
R. D. Bieniarz
D. Orals
R. L. Parks
H. Rustand
B. A. Zimmer

Report by:
B. A. ZIMMER
Project Engineer, Fire Protection Department

Reviewed by:
R. L. PARKS
Senior Project Engineer
Fire Protection Department

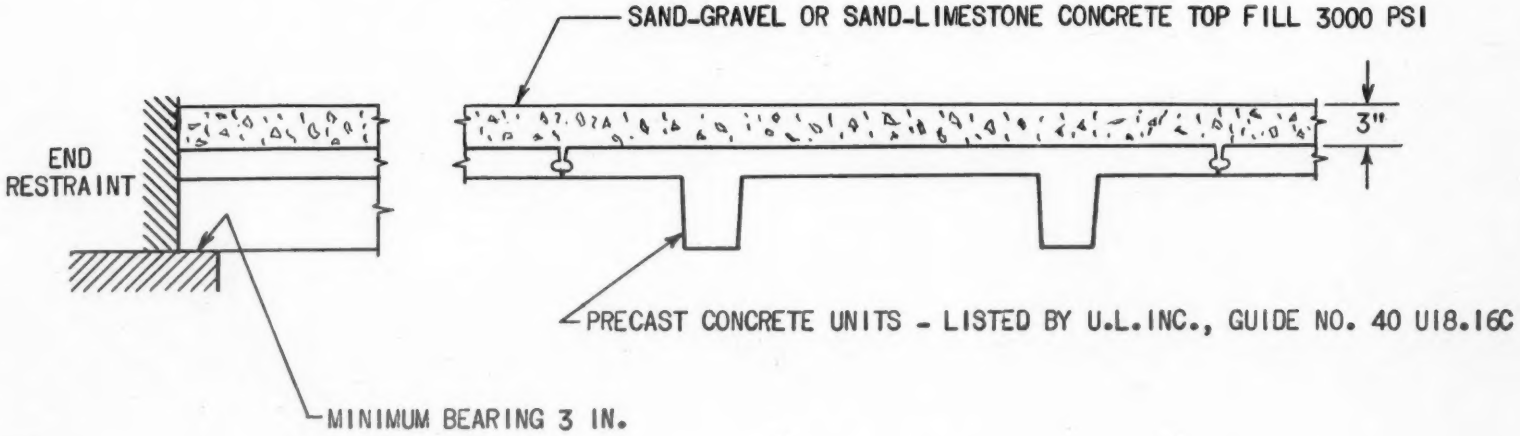
SUBMITTED:
A. J. STEINER
Managing Engineer, Fire Protection Department

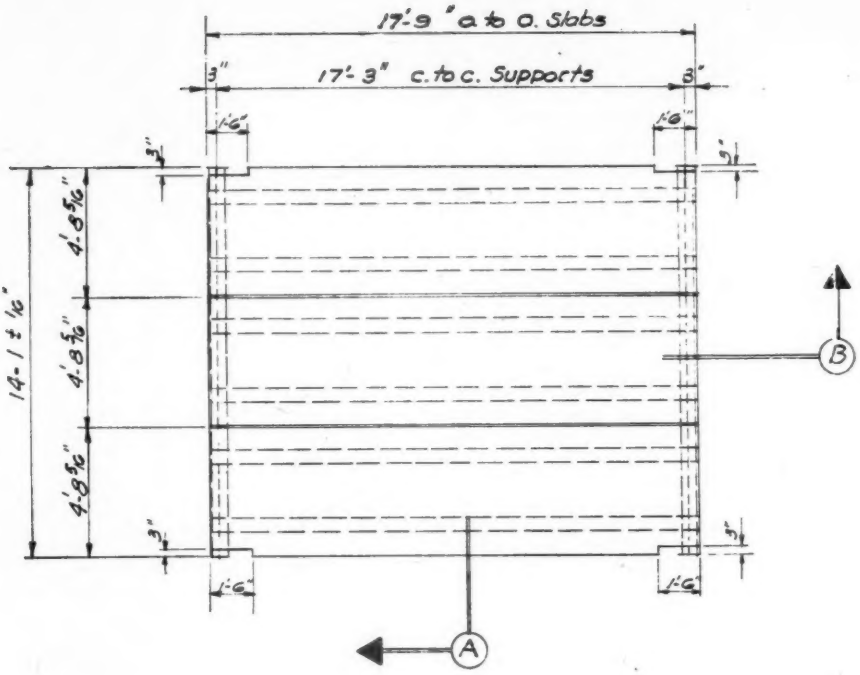
The foregoing Recommendation has been accepted June 4, 1958.
UNDERWRITERS' LABORATORIES, INC.
W. S. AUSTIN, Secretary

BAZ:MS

GUIDE NO. 40 U18
GENERAL INFORMATION (CONT'D)
FLOOR OR ROOF AND CEILING CONSTRUCTIONS

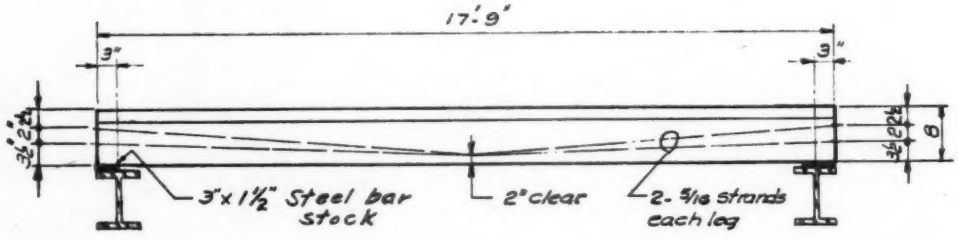
CLASS D - 2 DESIGNS
DESIGN NO. - 2 HR.


SAND-GRAVEL OR SAND-LIMESTONE CONCRETE TOP FILL 3000 PSI
3"
END RESTRAINT
PRECAST CONCRETE UNITS - LISTED BY U.L.INC., GUIDE NO. 40 U18.16C
MINIMUM BEARING 3 IN.

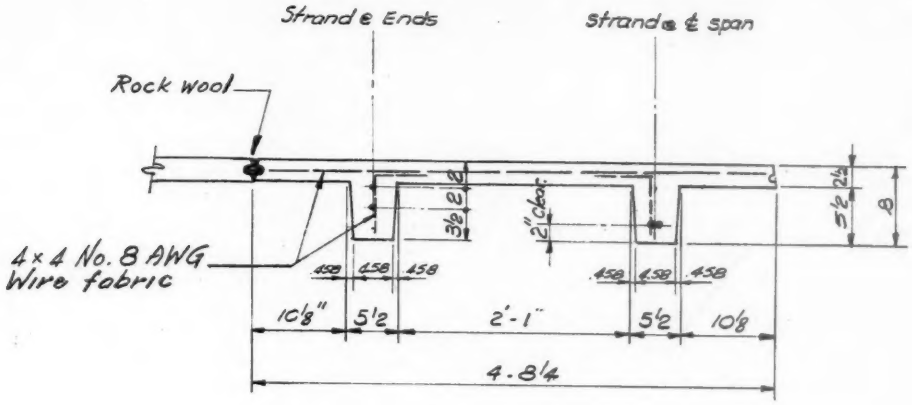


PLAN OF TEST SECTION
Scale 1/4" = 1'-0"

NOTE: The above slab make up provides for a clearance of 3/4" on all sides of the furnace opening.



SECTION-B
Not to scale



TYPICAL SLAB SECTION - Ⓐ
Scale 1" = 1'-0"

GENERAL NOTES

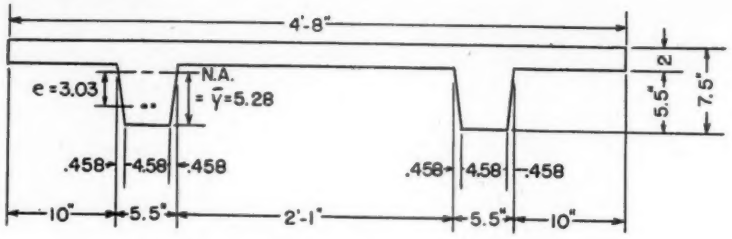
Concrete strength for design @ 28 days to be 5000 psi.
Prestressing steel: f_s = 250000 psi ultimate
Tensioning force each 5/16 strand = 10,150 #
Allowable design live loads:

Ultimate	1.4DL + 2.3LL	= 40.3 psf
Max. Tension	DL + LL - 210	= 40.0 psf
Cracking	DL + 1.5LL - 550	= 40.0 psf

Actual depths of members tested were as shown, namely 2-1/2" for the slab and 8" total depth, but the contemplated thickness of the slab under Underwriters' Laboratories, Inc. inspection service will be 2" and the total depth 7-1/2" as shown in Figure 2 when used in conjunction with the required 3" topping.

Figure 1
R-4123-1

SECTION PROPERTIES



(2)(56)	= $\frac{A}{112}$ x $\frac{Y}{6.5}$ =		727.0	$\bar{y} = \frac{884}{167.4} = 5.28$
2 (4.58)(5.2)	= 50.4 x 2.75 =		138.7	
4 (.5)(.458)(5.2)	= $\frac{5.0}{167.4}$ x 3.67 =		$\frac{18.5}{884.2}$	e = 3.03 distance of A_s from N.A.

1/2 (56)(2)^3	= 37	I	$S_T = \frac{675}{2.22} = 304$
2(1/12)(4.58)(5.2)^3	= 127		$S_B = \frac{675}{5.28} = 128$
4 (.36)(.458)(5.2)^3	= 8		
112 (1.22)^2	= 167	Ad^2	$f_{c_t} = \frac{T}{167.4} - \frac{T\,(3.03)}{304}$ = -0.0040T
50.4 (2.53)^2	= 323		$+ \frac{T\,(3.03)}{128}$ = +0.0297T
5.0 (1.61)^2	= 13		
	675 = I about N.A.		.0237T

DESIGN LIVE LOADS

CRACKING

1. Assume modulus of rupture = 550 psi for 5000 psi conc.
2. Design for DL + 1.5 LL at $f_{c_{bottom}}$ = -550 psi.

$f_{c_{LL}} = f_{c_t} + 550 - f_{c_{LL}}$

$M = 8WL^2 = f\,(S)$

$W = \frac{8(f)(S)}{L^2}$

$W_{LL} = \frac{8(f)(S)}{12(1.5)(4.67)(L^2} = \frac{8(f_{c_{LL}})(128)}{12(1.5)(4.67)(L^2} = f_{c_{LL}} \times \frac{12.2}{L^2}$

FIG. 2
R 4123-1

CRACKING -(CONT)

Dead Load Moment = $\frac{(167.4)(17.25)^2}{8}$ = 6.22 -K

$f_{c_{DL}} = \frac{6.22\ (12)}{128}$ = 583 psi

f_{c_t} = 4 (10150)(.0297)(.85) = 1024

$f_{c_{LL}}$ = 1024 - 583 + 550 = 991 psi

$W_{LL} = 991 \times \frac{12.2}{(17.25)^2}$ = 40.6 PSF

ALLOWABLE TENSION

1. Allowable tension = 210 psi for 5000 psi conc.
2. Design for DL + LL at $f_{c_{bottom}}$ = -210 psi

$f_{c_{LL}} = f_{c_t} + 210 - f_{c_{DL}}$

$W_{LL} = \frac{8\ (f_{c_{LL}})\ (128)}{12\ (4.67)\ (L^2)} = f_{c_{LL}} \times \frac{18.3}{L^2}$

$f_{c_{LL}}$ = 1024 - 583 + 210 = 651 psi

$W_{LL} = 651 \times \frac{18.3}{(17.25)^2}$ = 40.0 PSF

ULTIMATE

Design for 1.4 DL + 2.3 LL

Kd = $\frac{58000}{56\ (5000)(.85)}$ = .244 jd = 7.5 - 2.25 - 0.12 = 5.13

$M_u = \frac{58000\ (5.13)}{12}$ = 24.8 -K

$1.4\ M_{D_L}$ = 1.4(6.22) = 8.70 -K

$M_u - 1.4\ M_{D_L}$ = 24.8 - 8.70 = 16.1 -K

$2.3\ \frac{(W_{LL})\ (4.67)(17.25)^2}{8}$ = 16100#

W_{LL} = 40.3 PSF

FIG. 2A
R 4123-1

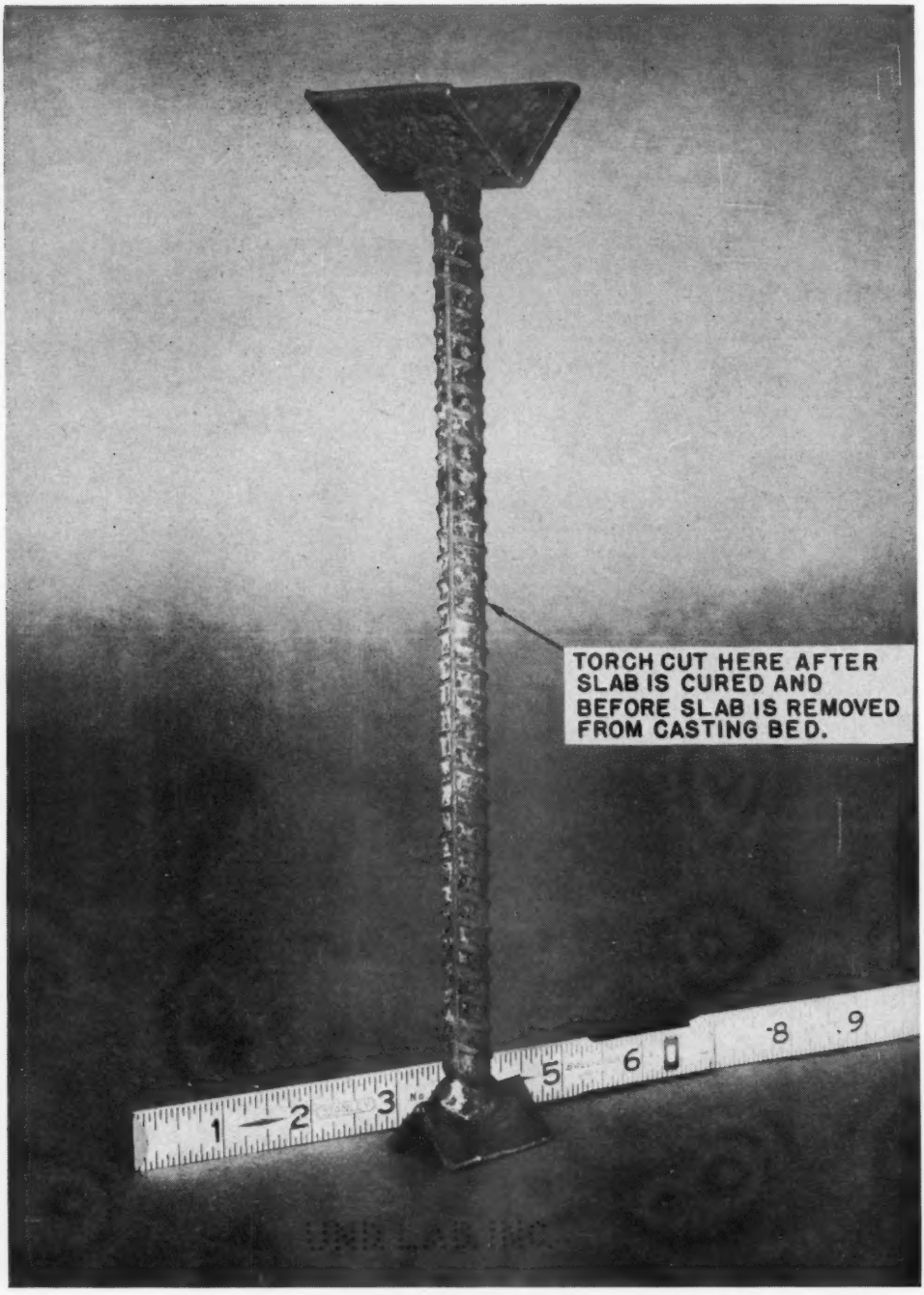


Figure 3 R-4123-1
Wire Reinforcing strand, hold down device

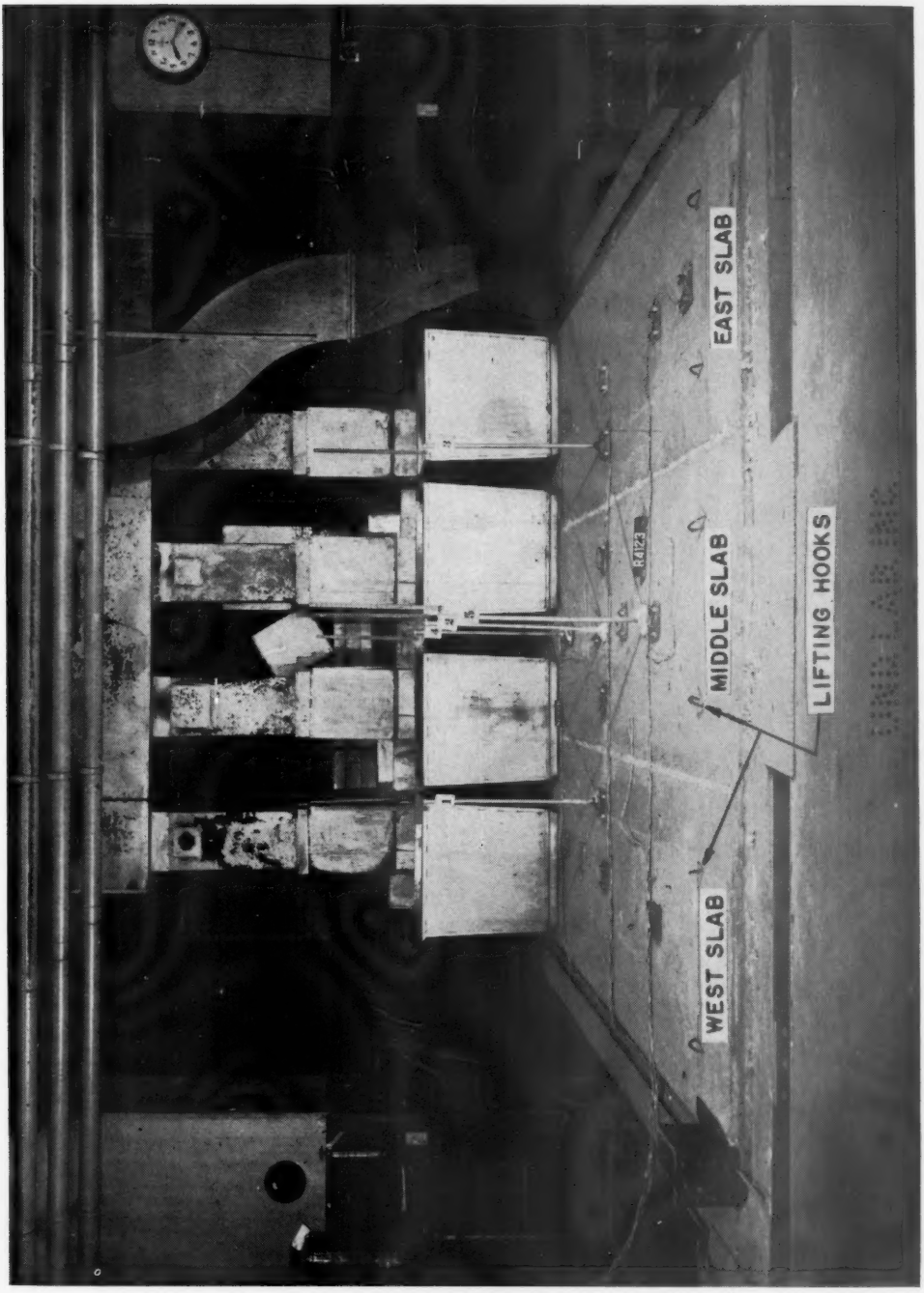


Figure 4 R-4123-1
Unexposed surface before fire endurance test showing deflection targets, thermocouples and loading method.

Figure 5 R-4123-1
Exposed side before fire endurance test

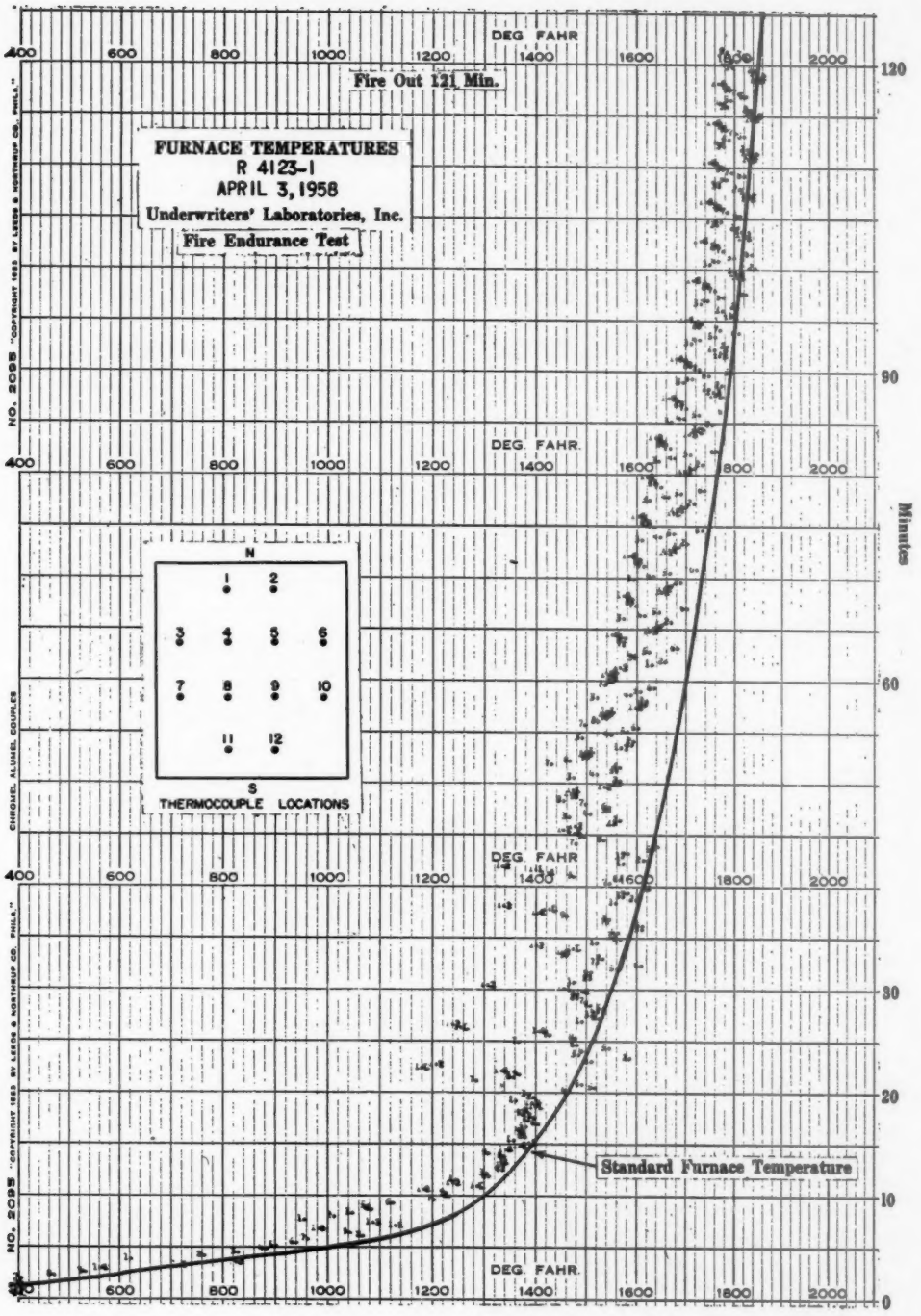

FURNACE TEMPERATURES
R 4123-1
APRIL 3, 1958
Underwriters' Laboratories, Inc.
Fire Endurance Test
Fire Out 121 Min.
DEG. FAHR.
400
600
800
1000
1200
1400
1600
1800
2000
120
90
60
30
20
10
0
Minutes
N
1
2
3
4
5
6
7
8
9
10
11
12
S
THERMOCOUPLE LOCATIONS
Standard Furnace Temperature
NO. 2085 "COPYRIGHT 1953 BY LEEDS & NORTHRUP CO., PHILA."
CHROMEL ALUMEL COUPLES

FIG. 6

UNEXPOSED SURFACE TEMPERATURES

R 4123-1

APRIL 3, 1958

Underwriters' Laboratories, Inc.

Fire Endurance Test

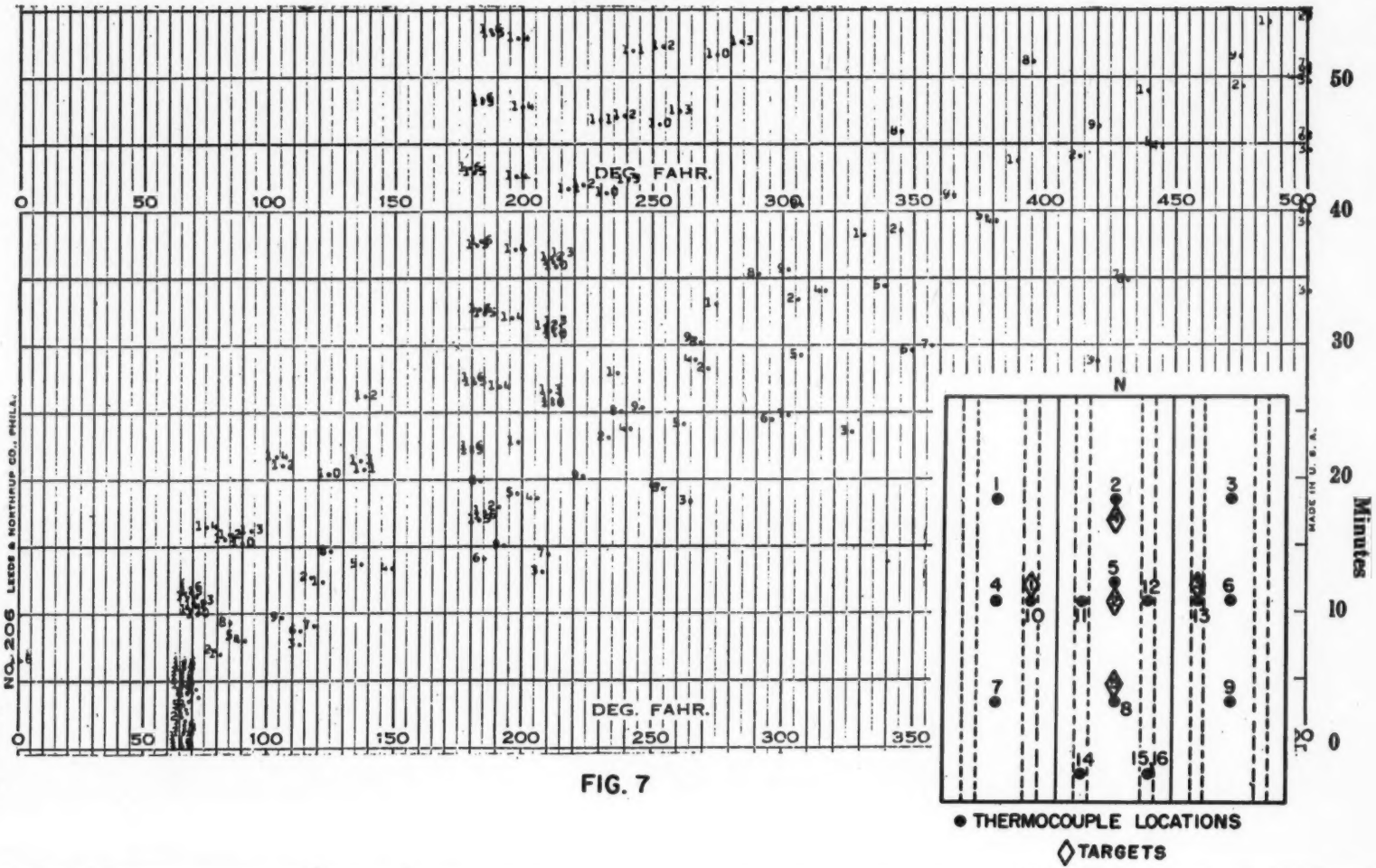


FIG. 7

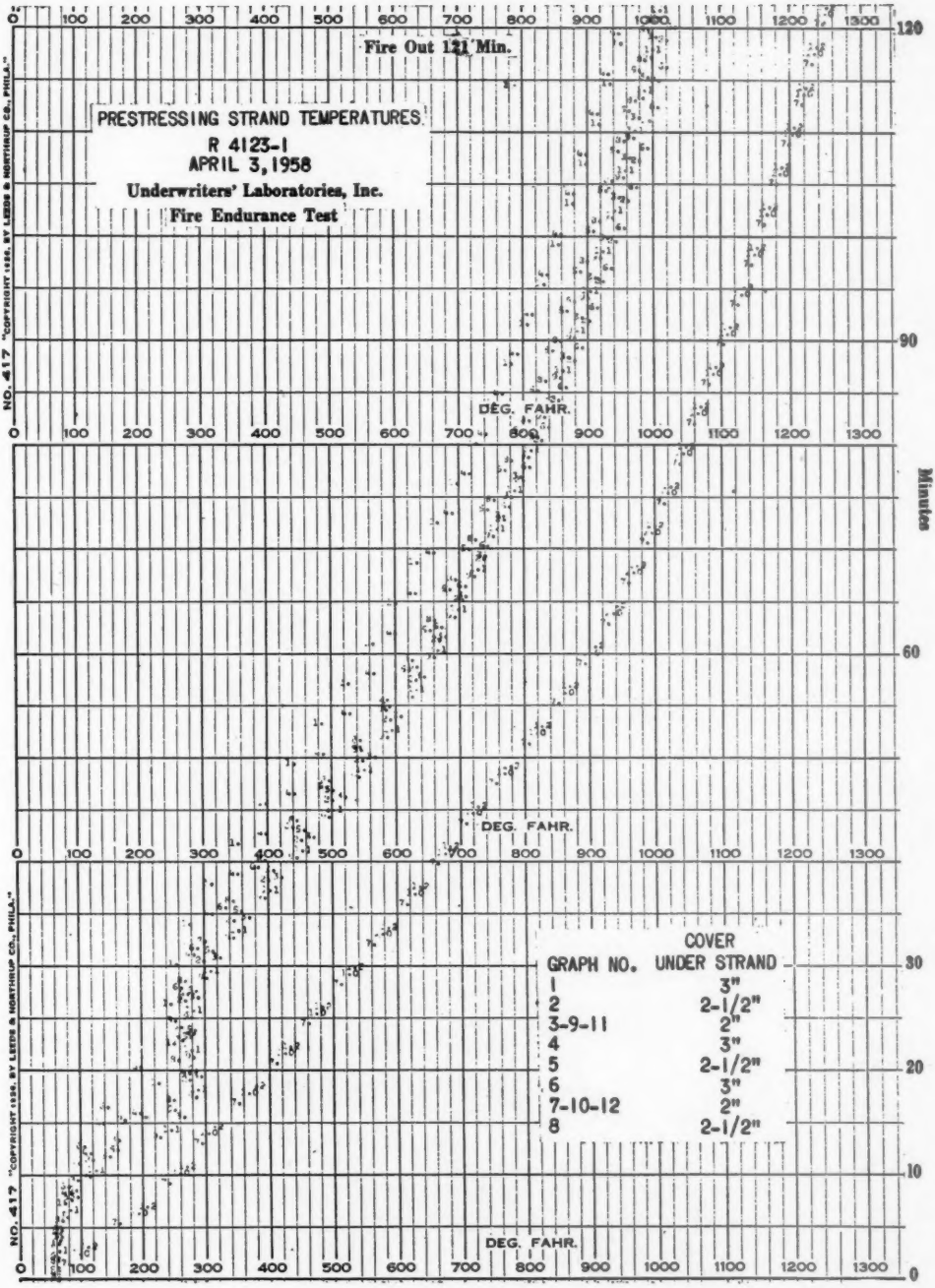

PRESTRESSING STRAND TEMPERATURES
R 4123-1
APRIL 3, 1958
Underwriters' Laboratories, Inc.
Fire Endurance Test
Fire Out 121 Min.
DEG. FAHR.
Minutes
COVER
GRAPH NO. UNDER STRAND
1 3"
2 2-1/2"
3-9-11 2"
4 3"
5 2-1/2"
6 3"
7-10-12 2"
8 2-1/2"
NO. 417 "COPYRIGHT 1956, BY LEEDS & NORTHRUP CO., PHILA."

FIG. 8

Figure 9 R-4123-1
Exposed surface after fire endurance test

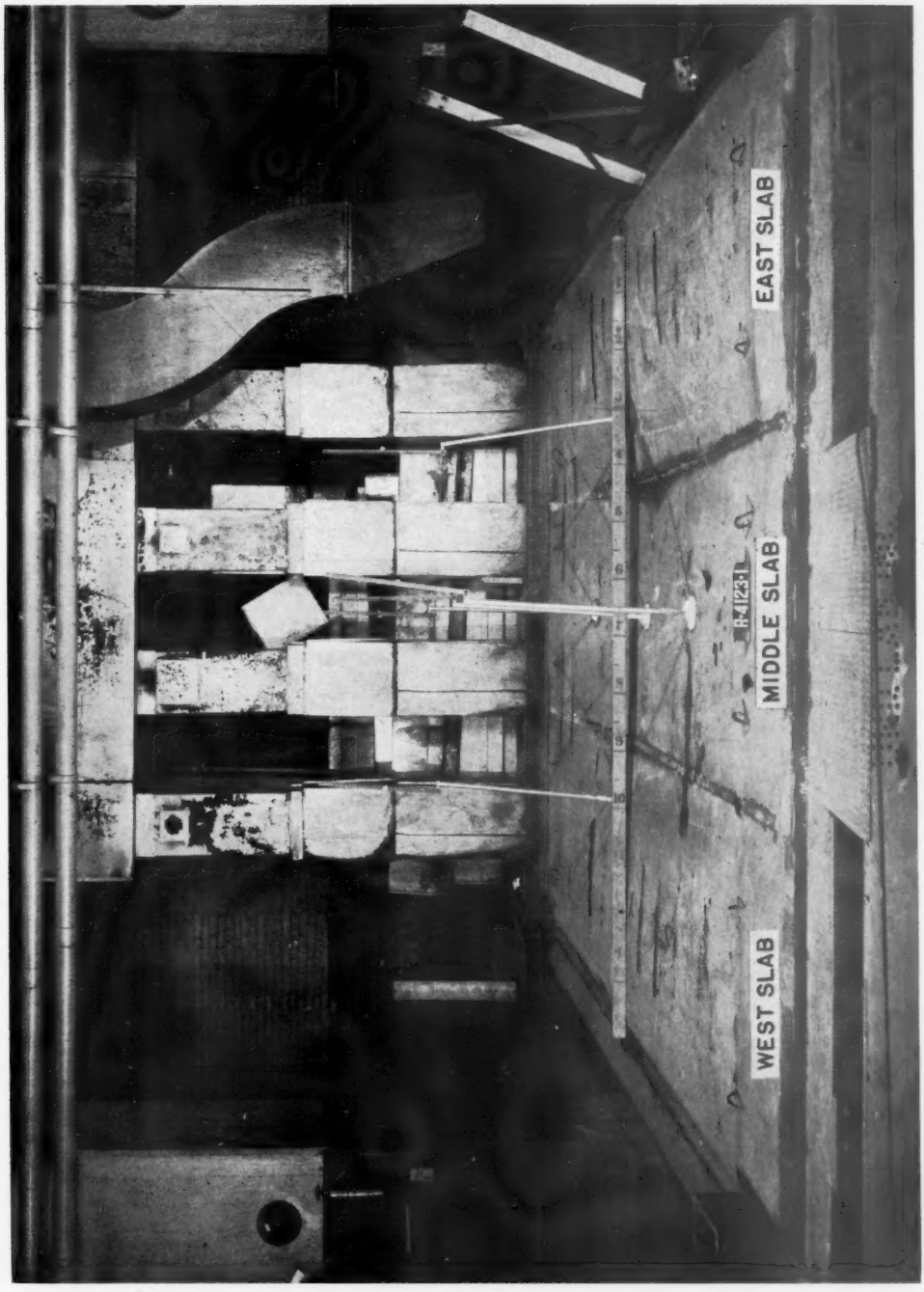


Figure 10 R-4123-1
Unexposed surface after fire endurance test

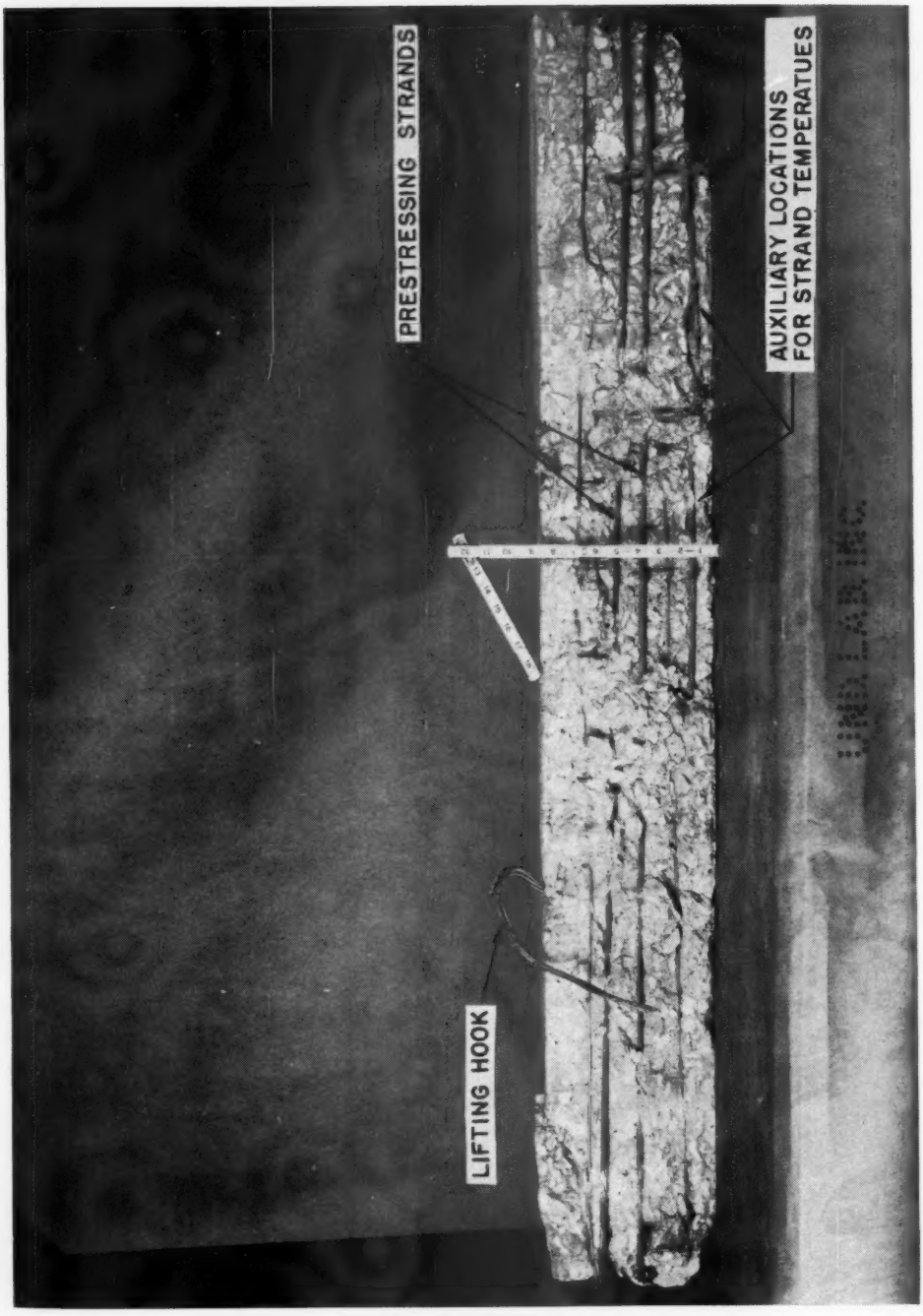


Figure 11 R-4123-1
Cross section of tee after fire endurance test

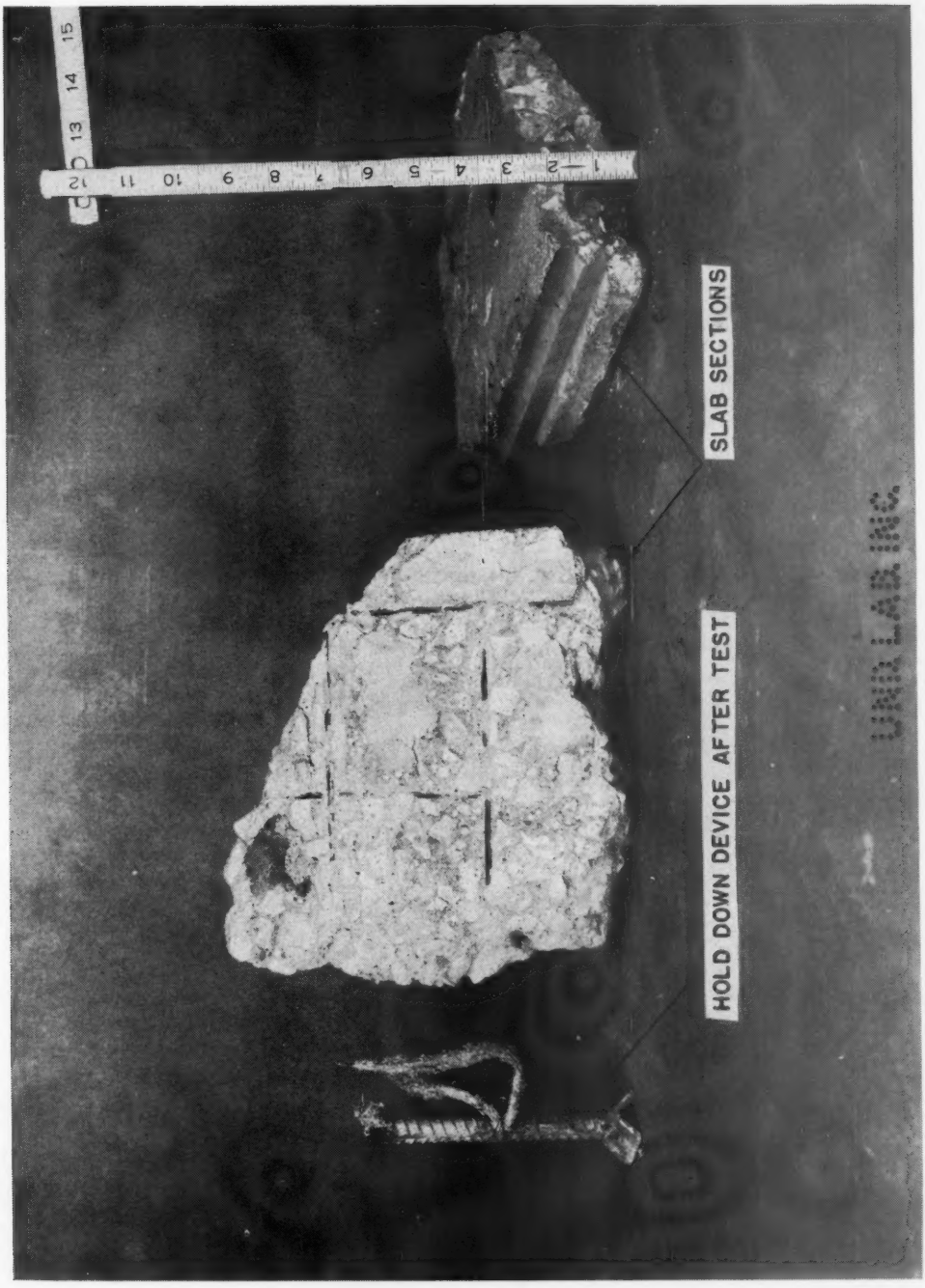
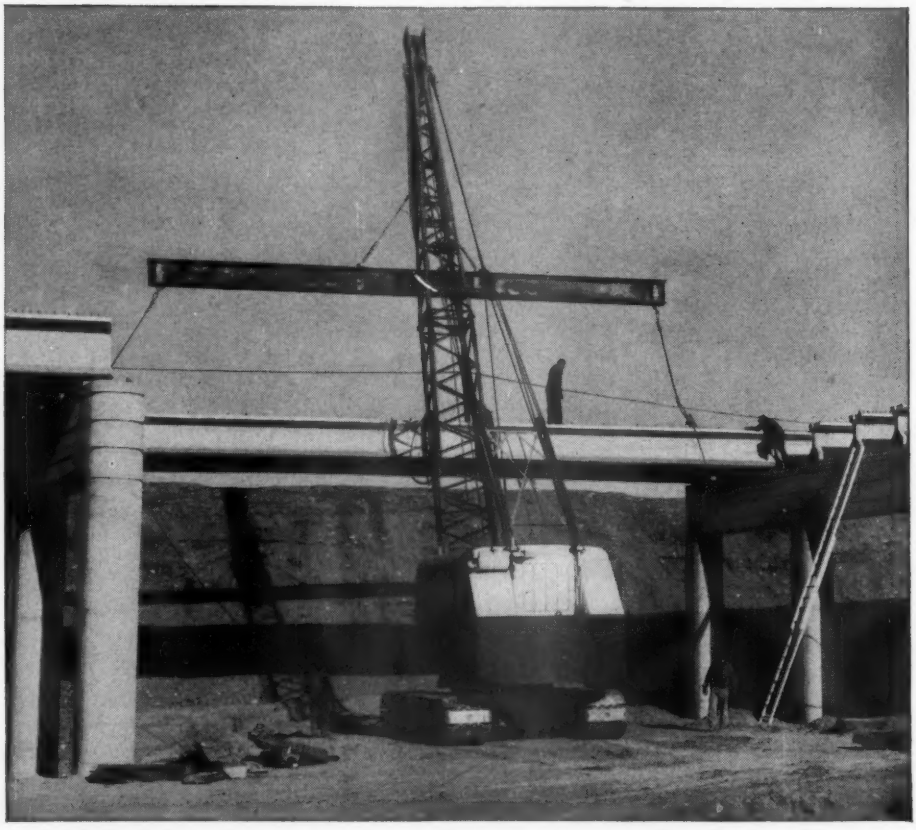


Figure 12 R-4123-1
Typical sections of slab after fire endurance test

On the Garden State Parkway . . .

405 prestressed beams



PLACING MAIN SPAN GIRDERS—A crane with a spreader beam is erecting a main span girder prestressed with USS American Super-Tens Stress-Relieved Strand. Note the ease of erection.

VISIT OUR BOOTH AT THE PCI CONVENTION, CHICAGO, SEPTEMBER 22-25.

USS **American Super-Tens Stress-Relieved Wire & Strand**

These people built this section of the Garden State Parkway: Design Engineers: Fay, Spofford & Thorndike, Inc., Boston, Mass. • Contractor & Manufacturer of Prestressed Beams: Reid Contracting Company, Inc., Woodbridge, New Jersey; L. W. Lancaster, Chief Engineer • Consulting Engineer for Contractor: Charles C. Zollman & Associates, Newtown Square, Pennsylvania.

were produced in 81 days

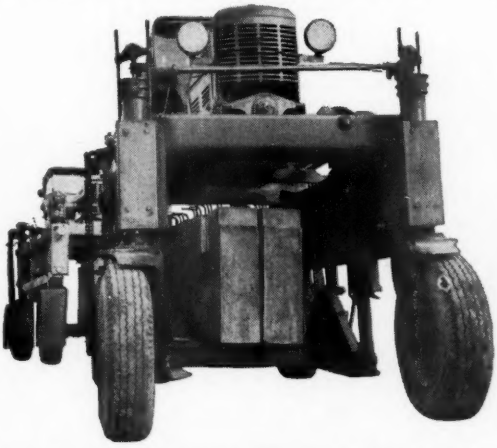
Linking New Jersey with New York and New England, the recently completed section of the Garden State Parkway is 9¼ miles of ultramodern highway. Along this new super-road there are eighteen prestressed concrete bridges. USS American Super-Tens Stress-Relieved Strand was used on this modern superhighway development.

The manufacturer of the prestressed beams for these bridges produced more than 400 prestressed beams in eighty-one days.

Prestressed concrete is a proven construction material with unlimited possibilities in building roofs, floors, walls, beams, slabs, columns, and foundations, as well as for bridges. American Steel & Wire pioneered in this development in 1951 by being the *first* to develop a new product—special high tensile strength strand for the first pretensioned bridge in this country. American Steel & Wire has a large engineering staff—men with experience in the uses of prestressed concrete. They will be happy to discuss its application to any of *your* construction needs.

For more complete details, call our nearest Sales Office today. Or write to American Steel & Wire, Rockefeller Building, Cleveland 13, Ohio.

USS, American and Super-Tens are trademarks



NEW WAY TO MOVE GIRDERS—Here a straddle truck is transporting a girder from the prestressing plant to the job. This was a time- and money-saving way to transport prestressed girders. Construction was speeded up because the girders were precast, then transported to the job site for immediate erection.

HERE IS the new USS American Super-Tens Stress-Relieved Strand reel furnished in standard sizes of 50" and 44". The new 2-ply construction resists warping and splitting, resulting in longer service life.

American Steel & Wire
Division of USS United States Steel

Columbia-Geneva Steel Division, San Francisco, Pacific Coast Distributors • Tennessee Coal & Iron Division, Fairfield, Ala., Southern Distributors
United States Steel Export Company, Distributors Abroad

P.C.I. STANDARDS FOR PRESTRESSED CONCRETE PLANTS

(TENTATIVE)

PLANT STANDARDS COMMITTEE

J. Ashton Gray, Chairman
S. L. Selvaggio
Douglas P. Cone

•

TECHNICAL ACTIVITIES COMMITTEE

Charles C. Zollman, Chairman

Separate reprints are available at $1.00 each (50c PCI members) from the Publication Office, Prestressed Concrete Institute, 3132 N. E. Ninth Street, Fort Lauderdale, Florida.

CHAPTER 1—INTRODUCTION

101—Objective

The objective of these regulations is to establish minimum standards for prestressed, precast concrete manufacturing plants. These standards will cover materials used, plant equipment, personnel, design, and central casting yard manufacturing techniques.

These minimum standards do not relieve the prestressing plant of any requirement which might be made by a state or other recognized agency. Special provisions and specifications must be met.

102—Scope

This regulation covers linear prestressing of precast members for buildings, bridges and miscellaneous structures and structural units and will include pre-tensioning, post-tensioning and the combination of both systems.

103—Definitions

The definition of terms used herein shall conform to Standard Specifications adopted by the Prestressed Concrete Institute and "Tentative Recommendations for Prestressed Concrete" by Joint ACI-ASCE Committee 323.

CHAPTER 2—MATERIALS

201—PRESTRESSING STEEL

201.1—Strand

Small diameter strand shall be of the 7-wire stress-relieved type and shall meet the standards set down in ASTM Specifications A-416-577 and the latest PCI Standard Specifications. The nominal sizes shall be 1/4", 5/16", 3/8", 7/16" and 1/2".

201.2—Wire

High tensile strength single wire shall meet the standards set down in PCI Standard Specifications.

201.3—Bars

High strength alloy bars shall meet the standards set down by latest PCI Standard Specifications.

202—REINFORCING STEEL

All bars and fabric for concrete reinforcements shall meet standards as set down by the latest appropriate ASTM Specifications.

203—CONCRETE

Concrete shall meet the required strength called for on the plans and shall be manufactured, transported and placed in accordance with the latest recommended practices of the American Concrete Institute.

203.1—Portland Cement

Cements used will conform to the following:

(a) Specifications for Portland Cement (ASTM C150).
(b) Specifications for Air-Entraining Portland Cement (ASTM C175).
(c) Specifications for Portland-Pozzolan Cement (ASTM C340).

203.2—Concrete Aggregates

Concrete Aggregates will conform to:

(a) Specifications for Concrete Aggregates (ASTM C33).
(b) Specifications for Lightweight Aggregates for Structural Concrete (ASTM C330).

The size of coarse aggregates will conform to spacing of reinforcing steels and generally shall be no larger than one (1) inch.

203.3—Mixing Water

Mixing water must be clean and free of injurious quantities of substances harmful to concrete or to prestressing steel. Sea Water shall not be used.

203.4—Admixtures

Admixtures to provide air-entraining and/or retarding-densifying action may be approved. Calcium Chloride will not be used.

203.5—Proportioning, Batching and Mixing

Proportioning, batching and mixing shall conform to the latest practices recommended by the American Concrete Institute. Particular reference should be made to the following:

(a) ACI Manual for Concrete Inspection.
(b) ACI Standards for Winter Concreting Methods (ACI 604).
(c) Selecting Proportions for Concrete (ACI 613).
(d) Measuring, Mixing and Placing Concrete (ACI 614).
(e) Standard Specifications for Ready-Mix Concrete (ASTM C94).

203.6—Strength

Concrete strengths should conform to those called for on plans and in no case should strengths be less than those set forth in PCI Standard Specifications.

204—ANCHORAGES FOR PRESTRESSING ELEMENTS

204.1—Pre-tensioning Strand

Pretensioned strands shall be secured by suitable anchorage devices capable of developing at least 85% of the ultimate strength of the strand. High tensile steel tapered casings fitted with segmented, serrated chuck jaws have proved satisfactory.

204.2—Post-tensioning Cables

Post-tensioning strand of very large diameter should have end fittings which are capable of developing the ultimate strand strength. For parallel-lay wire cables, button-head, sandwich plate, or conical wedges are normally used. Where small diameter strand is used in post-tensioning, conical wedges will normally be used. All types of anchorages referred to should have an ultimate strength of at least equal to the tendons to which they are attached.

204.3—Post-tensioning Bars

Threaded ends or wedge type anchors will normally be used for post-tensioning steel bars. The ultimate strength of these anchors should at least equal the ultimate strength of the bars to which they are attached.

CHAPTER 3—PLANT EQUIPMENT

301—SITE

The plant site should consist of an adequate area for casting operations and for storage. Great care must be exercised that the plant area is adequately drained so that the surface can be well stabilized or preferably paved. Casting yard areas must be kept clean and orderly to insure smooth and efficient operation and to insure maximum safety to plant employees.

302—CASTING BEDS

Casting beds may be constructed of steel, prestressed concrete or reinforced concrete. They must be so designed that they will safely take the stresses applied to them without appreciable deflection. Normally, casting beds should be slightly above grade to insure that they will not be submerged due to rains if in uncovered areas or from accumulation of condensate as a result of steam

curing operations. Anchorage abutments should be one or more of the following types:

(a) Piling driven to sufficient depths to safely resist overturning forces.
(b) Mass concrete (Gravity Type).
(c) Abutments post-tensioned to a beam type bed.
(d) Compression strut type.

Casting beds and abutments will be so designed that they are capable of safely resisting all forces applied to them without appreciable movement. These forces will consist of compression and eccentric forces due to end jacking operations, upward forces at hold-down points where strands are draped, downward forces due to dead weight of the members being cast.

303—TENSIONING EQUIPMENT

303.1—Jacks

Hydraulic jacks of sufficient capacity and stroke will normally be used for tensioning strand. Either multiple or single strand tensioning will be acceptable. Tensioning jacks must be equipped with large face gauges which indicate small increments to insure accuracy of reading. Gauges shall be calibrated for the jacks with which they are used. Two calibrated gauges should be provided for jacks, one of which is used during routine stressing, while the other is locked out and used only by the inspector or plant quality control engineer to verify the accuracy of the working gauge. Calibration of jacks will be done by a reputable testing laboratory.

303.2—Hydraulic Pumps

Hydraulic pumps should be of sufficient capacity to accomplish the stressing operation in a reasonable time. Pumps should be located as near as possible to jacks which they serve in order to eliminate as much as possible line friction between pumps and jacks. With most hydraulic equipment, momentary psi fluid pressures may go very high. Consequently it is essential that double extra strong steel piping or adequate strength tubing and reinforced flexible hoses and connections be used at all times.

303.3—Tensioning Bolts and Nuts

All tensioning bolts and nuts must be of a satisfactory grade of steel and should be of such size that they will operate with safety under the highest operating stresses applied to them.

303.4—Templates and Pull Headers (or Carriages)

All templates, pull headers, carriages and end-blocks will be fabricated or cast steel and will be so designed that they will safely carry all loads applied to them.

303.5—Dynamometer

When multiple strands are tensioned simultaneously, plants will be equipped with approved type dynamometers for equalizing the initial stress on all strands prior to application of the full tensioning load with the master jack. The capacity of the dynamometer should be such that the desired readings are in the middle to upper range.

304—FORMS

Fabricated steel forms will be used. All forms must be well braced and stiffened to avoid undesirable deformations under pressure of wet concrete and shall have smooth joints and inside surfaces. Wood or concrete forms can be approved for special and unusual items when required.

305—MATERIALS HANDLING EQUIPMENT

Materials handling equipment and machinery must be adequately designed to safely strip members from casting beds, transport to storage areas and to load members for shipment. Equipment generally used will be hydraulic lift trucks, straddle carriers, motor cranes, bridge cranes and gantry cranes.

306—CONCRETE MIXING EQUIPMENT

Concrete mixing equipment may be any approved make of the following types:

(a) Truck mounted transit mixer.
(b) Central drum type stationary mixer.
(c) Pan type mixer.

Sufficient mixer capacity will be required to insure no undue delays during placing operations.

307—VIBRATORS

Approved type high frequency internal and/or external vibrators will be used for proper compaction of the wet concrete. Vibrators should be pneumatic or power driven types and in all cases the amplitude and speed ranges will be suitable for proper compaction. At least one spare vibrator will be kept as a standby during casting operations.

308—HEATING EQUIPMENT

Heating equipment for accelerated curing may be of the following types:

(a) Steam
(b) Hot Water
(c) Hot Oil
(d) Other approved type — radiant.

Capacity of heating equipment should be adequate to maintain the required bed temperature specified in Chapter 6 of these regulations.

309—CONCRETE STRENGTH TESTING EQUIPMENT

Plants should be equipped with test cylinder molding equipment and compression testing apparatus so that concrete strengths can be checked without delay prior to detensioning or post-tensioning operations. For plants not so equipped, test cylinders will be made and checked by an approved commercial laboratory.

CHAPTER 4—PERSONNEL

401—ENGINEERING SECTION

401.1—Prestress Design

The design of prestressed members will be done by engineers competent in prestress design. All design work must conform with criteria specified in the latest revision of standard PCI Specifications for Pre-tensioning and Post-tensioning and/or with "Tentative Recommendations for Prestressed Concrete" by ACI-ASCE Joint Committee 323, and subsequent generally accepted codes or specifications as approved by the Board of Directors of the Prestressed Concrete Institute.

401.2—Engineer

Each plant will be required to have an engineer well founded in prestressed design on its own staff or on a retained basis.

402—PLANT SUPERINTENDENT

The plant superintendent must be well qualified in all phases of the production of prestressed members and acceptable manufacturing techniques.

403—PLANT FOREMAN

All plant and bed foremen must be well qualified for the jobs assigned to them.

404—ERECTION SUPERVISOR

Each plant should have a competent installation supervisor whose suggested duties are as follows:

(a) To check the progress of jobs in process to assure that the structure is ready to receive the prestressed members before shipment, and that no conditions exist which might cause an unsatisfactory installation.

(b) To inspect at the casting yard all manufactured members for conformance with plans prior to shipment.

(c) To supervise handling and installation of members in structure to insure that installation is in conformity with the plans.

(d) To check after every erection phase with the prime contractor or owner to assure satisfaction with the work done.

(e) To make a written report of any irregularities observed (such as dropping a beam during handling).

CHAPTER 5— DESIGN

501—DESIGN REQUIREMENTS

Plant management must comply with the requirements set down in latest revision of PCI Standard Specifications and/or "Tentative Recommendations for Prestressed Concrete" by Joint ACI-ASCE Committee 323.

CHAPTER 6—MANUFACTURING TECHNIQUES

601—PRESTRESSING STEEL

601.1—Protection

All prestressing strand, wire and bars will be sheltered from the elements to prevent undue rust before use. These items will be so handled that no deleterious substances such as grease, oil, wax, etc. will come in contact with them prior to placement of concrete.

601.2—Tensioning

Proper and accurate tensioning of prestressing strand, wire, cable and bars is most important. The accuracy of stressing will be checked by calibrated gauge and cross checked by the elongation of the steel. Proper allowances will be made for the amount of slip normally expected in the "bite" or seating of anchorage devices.

601.2.1—Pre-tensioning

When pre-tensioning is employed, care must be taken to pay out strand and wire in such a way that substances injurious to bond such as oil, grease and wax will not come into contact with the steel. If bond breakers are sprayed on form surfaces after placing of the prestressing steel, suitable hoods or shields will be placed over the steel to eliminate the possibility that this material will come in contact with the steel. Where necessary, paper or other shielding material should be placed temporarily over pallets to insure that strands and wires will be kept clean. Strand and wire "grips" or wedges must be kept clean and free of grit. It is also advisable to wrap wedges or chuck jaws with thin waxed paper or to dip in paraffin to facilitate unlocking without damage from unnecessary hammer blows or the like. When there is a differential of over five (5) per cent between the steel stress determined from adjusted

elongation and from the gauge reading, the engineer should be consulted and the cause of the discrepancy should be ascertained and corrected. When multiple strands or wires are tensioned simultaneously, an approved dynamometer should be used to ascertain that the same initial stress is in each element prior to completing the full stressing operation.

601.2.2—Pre-tensioning Draped Strand

When strands are draped in pre-tensioning it must be done along technically sound lines to insure that the strands are uniformly stressed and that the results achieved are satisfactory. Stress differentials in a bed should not exceed five (5) per cent.

601.2.3—Post-tensioning

When post-tensioning is used the prestressing force as determined by total elongation (corrected for assumed friction loss and anchorage set) should not vary more than five (5) per cent when compared to the corresponding gauge reading. If this differential is greater than five (5) per cent, the engineer should be consulted and the cause of the discrepancy shoud be determined and corrected before proceeding. When grouting is specified for post-tensioned members, it should be accomplished in accordance with the provisions of the latest PCI Standard Specifications for Post-tensioning and/or with recommendations included in Joint ACI-ASCE Committee 323 Report.

602—FORMS

602.1—Care

All metal forms and molds must be kept clean and in good repair. Particular care will be exercised in the handling and anchoring to eliminate harm to surfaces or alignment. Undesirable flaws and blemishes will be avoided.

602.2—Placing

Forms should be stripped and placed in an orderly fashion and in such a way as to prevent distortion.

602.3—Alignment

Accurate alignment of forms must be strictly maintained throughout the casting operation. Smooth joints and inside surfaces must be maintained. Mismatch of forms where sections join will not exceed the following tolerances:

For small sections - - 1/16"
For medium sections - 1/8"
For large sections - - 1/4"

602.4—Bond Breakers

Bond breakers which are used to release forms from cast members should be of an approved type which will eliminate as far as is possible air and water bubbles on the surface of the cast member. Water soluble oil or grease suitably diluted with water and silicone type bond breakers have been found satisfactory.

603—CONCRETE

603.1—Batching

Proportioning and batching of component materials for concrete will be done by weight with accurate adjustments made for absorbed and free moisture in the aggregates.

603.2—Mixing

Mixing of the concrete may be done in central drum mixer, pan type mixer, or transit mixer of approved design. Time of mixing in the type used

should be sufficient to obtain a well mixed, dense and consistent concrete of the lowest slump which can be placed and properly compacted. Over mixing will be avoided.

603.3—Transporting

Concrete will be transported in an approved type drum, bucket or other container to assure delivery to forms without delay and without segregation of the components of the plastic concrete.

603.4—Placing

The placing system in the plant must insure obtaining a uniform, dense, and high grade concrete in all parts of the members under all working conditions.

603.5—Compaction

Internal or external vibration, or both, will be required as it is necessary to produce uniformly dense concrete without segregation.

603.6—Finishing

The finishing of concrete members will be as called for on plans and will in all instances evidence a high grade of skill and workmanship.

603.7—Curing

The curing operation is one of the most important phases of plant operation and must be properly done if the desired concrete strengths are to be achieved.

603.7.1—Wet Burlap

If wet burlap blankets are used for curing, they should be placed over the entire exposed concrete surfaces as soon as possible after the finishing operation has been completed. At least two (2) layers of burlap should be used. In certain thin sections, the large exposed areas such as decks of double-tee slabs and channels must be covered immediately after placing if shrinkage drying cracks are to be eliminated. After the placing of burlap the moisture content should be maintained either by soaker hoses or by frequent spraying with water.

603.7.2—Membrane

Approved types of membrane curing compound may be used. Great care must be taken however that this type of curing material will provide a water tight film over the entire exposed surface.

603.7.3—Radiant Heat

Heat curing by the use of hot water, hot oil, or other approved means may be used provided acceptable temperatures are achieved and provided the exposed surfaces of cast members are blanketed or coated to properly prevent water loss and maintain moisture content at the surface of the member.

603.7.4—Steam

Heat curing by use of steam will be approved. This is normally accomplished by shrouding or hooding the entire casting bed and introducing steam by means of perforated steam lines. Steam pressures must be sufficiently equalized and perforations sufficiently close together to provide an even temperature over the entire bed being cured. It is also essential that the atmosphere within the curing chamber be kept saturated at all times.

603.7.5—Cycle

When heat curing is used the temperature rise should not begin before the concrete has taken its initial set (normally 2 to 4 hours after placing). Great care must be exercised to see that heat is introduced gradually and reduced gradually to avoid thermal shock to the concrete. The heating cycle should

continue long enough to produce the specified concrete strength.

603.7.6—Temperature

In order to insure proper temperatures, regulators and recording devices will be used in all cases. The upper limit of curing temperature should not exceed 160° Fahrenheit.

604—STRIPPING

604.1—Transfer of Prestressing Force to Members

Any violent shock should be avoided when stress is transferred to precast members.

604.1.1—Pre-tensioning

Prestressing force should be transferred to members by releasing strand and wire gradually with hydraulic jacks in all cases where this is possible. Where release by jack is impracticable, each strand should be burned simultaneously at selected exposed points between anchorages and the sequence should follow a predetermined pattern to equalize the forces being transferred to the various areas of the cross section of the member. For heat release, a low-oxygen flame should be used and at least a 4" section of wire be uniformly heated to reduce tensile strength and prevent the shock encountered when strands are burned with a high-oxygen flame at a single point.

604.1.2—Post-tensioning

Prestressing forces should not be applied to members to be post-tensioned until concrete strengths have reached those specified in the plans or at least those specified in PCI Standard Specifications. Stresses introduced by post-tensioning will normally be gradual which will eliminate any possibilty of shock transfer.

605—HANDLING OF CAST MEMBERS

605.1—Location of Pickup Points

Extreme care must be exercised to see that pickup points are located so as to insure that cast members are not damaged in handling. It is normal practice to place pickup points inside the bearing points to facilitate slinging. Allowable cantilevers will vary with the type of member handled. Consequently, it is of paramount importance that the cantilevered sections do not exceed lengths specified by the engineer to assure that damage will not result.

605.2—Lifting Eyes

It is essential that lifting eyes are adequate to safely handle the members in which they are installed. Great care must be taken that they are adequate from a strength standpoint and that they are embedded deeply enough into member to prevent pulling out.

605.3—Stacking in Storage

Cast members will be stacked in the storage area in such a way that all members will bear at the design bearing points. Where members are stacked one upon the other the method should insure that damage will not occur due to the dead weight superimposed on the lower members. Every precaution should be taken to see that the soil in the storage area is adequately stable to prevent uneven sinking of the foundation which might cause overturn of stacked members during extremely wet weather.

605.4—Loading and Transportation

Great care must be taken in the loading for transportation of the finished

products. Bearing points must conform within close tolerances to those for which the members are designed. After loading, all members should be secured by hold-down chains or bands and properly chocked to prevent movement and damage during transportation.

CHAPTER 7— INSPECTION

701—INTERNAL SYSTEM

Each plant will establish an internal system of inspection which will remain in constant operation to assure supervisory personnel that minimum standards set down herein are complied with at all times.

702—EXTERNAL SYSTEM

There is set down below a recommend Inspection Schedule to guide retained commercial testing laboratories or other regulating agencies to assure quality control.

702.1—Prestressing Steel

Regulating Agency will review mill certification furnished by the manufacturer of prestressing steel for each shipment from which identifiable reels and/or bars were shipped to insure compliance with Section 201 of these regulations.

702.2—Random Tests of Concrete Strengths

Concrete test cylinders will from time to time be made and random and laboratory tested as a recheck of the efficiency and accuracy of plant testing procedures. These spot checks will be made not less than once per month.

702.3—Calibration of Jacks and Gauges

All jacks, rams, and gauges will be calibrated when installed by the use of proving rings or other approved devices to assure that discrepancies between jack loads and gauge readings do not exceed five (5) per cent. Rechecks of these calibrations will be made at least each six (6) months.

702.4—Quarterly Checks and Inspections

Regulating Agency will check the following at installation and at least each three (3) months thereafter.

702.4.1—Casting Beds and Anchorage Abutments

Will be checked to assure that casting beds and anchorage abutments are properly designed and adequate to withstand the forces applied to them. Specific checks will be made by the use of independent reference points to detect any yielding or slippage of intolerable magnitude between initial stress and final release.

702.4.2—Batching Scales

Will be checked for accuracy.

702.4.3—Mixing Equipment

Will be checked to determine suitability for the purpose used and its physical condition.

702.4.4—Concrete Aggregates, Cement and Mixing Water

Will be obtained for laboratory tests to determine that they meet the latest revision of ASTM and PCI Standards as to soundness, gradation, deleterious substances, etc.

702.4.5—Daily Concrete Strength Records

Will be checked to insure that required strengths are achieved prior to release of pre-tensioned members and prior to post-tensioning operations.

702.4.6—All Plant Forms

Will be closely checked for flaws, blemishes, misalignment, etc. which might be sufficient to render them sub-standard to produce high quality members.

702.4.7—Prestressing Tendons

Will be checked to determine if they are accurately placed in accordance with approved shop plans and to assure that accurate tensioning is performed within tolerances specified.

702.4.8—Concrete Design Mixes

Used by the plant will be checked to determine if they are suitable and efficient for the purpose intended and to determine if accepted proportioning methods have been employed. Careful checks will be made to determine the reliability and accuracy of adjustments used for absorbed and free moisture in the aggregates.

702.4.9—Placement of Concrete

Will be checked to assure that placement, compaction and finishing are being performed in accordance with the latest practices recommended by the American Concrete Institute.

702.4.10—Transfer of Prestressing Forces

Will be checked to insure compliance with these regulations.

702.4.11—Curing Operations

Will be checked to assure that they comply with these regulations.

702.4.12—Handling Procedures

Will be checked to assure that cast members are handled, stored and shipped in accordance with these regulations.

702.4.13—Quarterly Plant Inspection Reports

By the Regulating Agency will be sent to the plant management.

products. Bearing points must conform within close tolerances to those for which the members are designed. After loading, all members should be secured by hold-down chains or bands and properly chocked to prevent movement and damage during transportation.

CHAPTER 7— INSPECTION

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Each plant will establish an internal system of inspection which will remain in constant operation to assure supervisory personnel that minimum standards set down herein are complied with at all times.

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Regulating Agency will review mill certification furnished by the manufacturer of prestressing steel for each shipment from which identifiable reels and/or bars were shipped to insure compliance with Section 201 of these regulations.

702.2—Random Tests of Concrete Strengths

Concrete test cylinders will from time to time be made and random and laboratory tested as a recheck of the efficiency and accuracy of plant testing procedures. These spot checks will be made not less than once per month.

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Regulating Agency will check the following at installation and at least each three (3) months thereafter.

702.4.1—Casting Beds and Anchorage Abutments

Will be checked to assure that casting beds and anchorage abutments are properly designed and adequate to withstand the forces applied to them. Specific checks will be made by the use of independent reference points to detect any yielding or slippage of intolerable magnitude between initial stress and final release.

702.4.2—Batching Scales

Will be checked for accuracy.

702.4.3—Mixing Equipment

Will be checked to determine suitability for the purpose used and its physical condition.

702.4.4—Concrete Aggregates, Cement and Mixing Water

Will be obtained for laboratory tests to determine that they meet the latest revision of ASTM and PCI Standards as to soundness, gradation, deleterious substances, etc.

702.4.5—Daily Concrete Strength Records

Will be checked to insure that required strengths are achieved prior to release of pre-tensioned members and prior to post-tensioning operations.

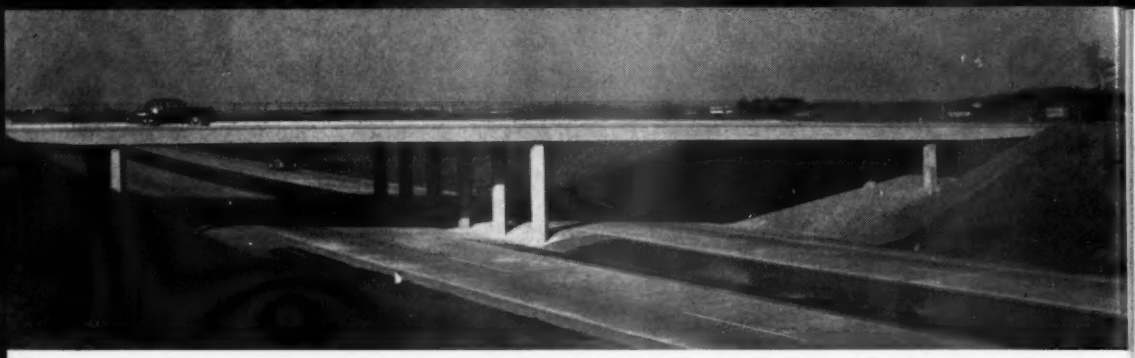

Fig. 1 Slab bridge over Danish turnpike (2 x 20m) with recessed abutments in order to increase visibility on the road.

Prestressed Concrete in Scandinavia

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1. Historical Review

One of the very first proposals concerning prestressed concrete was made by a Norwegian engineer, J. G. E. Lund, who in 1905 advanced the idea of using steel rods under tension (anchored with nuts) in reinforced concrete in order to avoid cracks in the concrete. He failed, however — as did many others later — due to the limited knowledge at that time of the shrinkage and creep of the concrete, and thus of the proper tension to apply to the rods.

In spite of this early attempt, prestressed concrete was not introduced to Scandinavia until 1942, at which time a "long line" factory was started in Stockholm. At about the same time a girder bridge was constructed in Sweden with a primitive sort of post-tensioning, using rods of steel outside the concrete, in order to attenuate the stresses in the reinforced sections of the main span of 72 meters.

It was, however, only after World War II that prestressed concrete became more used in Scandinavia. Long-line factories were founded in Denmark in 1947, in Finland in 1950 and in Norway in 1951. There are now (1957) about 10 of these factories in Scandinavia, the factory in Stockholm still being by far the biggest and only one in Sweden, whereas 4-5 factories of medium size are serving Denmark, which has a dense population compared to the other Scandinavian countries.

Prestressed concrete in the form of post-tensioning on the site was first employed in Denmark, where it was put at an early stage to many varying uses comprising of bridges, reservoirs, silos, industrial buildings, etc. The development in Sweden was at first confined to bridges, but is now

spreading to the same fields as in Denmark, and the same is true, to a lesser extent, for Norway, whereas the use of post-tensioned concrete in Finland has been rather sporadic.

2. Scope of Activities

As outlined in the previous section, the scope of activity of prestressed concrete in Scandinavia has covered most normal fields of this building procedure. The most important of these fields are mentioned below illustrated by typical or outstanding examples.

A. Bridges

A large number of medium sized bridges have been built in prestressed concrete, especially in Denmark and Sweden. Characteristic for these bridges is that most of them have been cut in-situ, using as simple a form as possible, i.e., slab bridges for spans to approx. 20-25 m or slab-frames with abutments in normal reinforced concrete. For spans up to 40-45 m slab-beam bridges are used. Most of these beam bridges have been made with simple rectangular beams connected with the slab, the whole section working together. The reason why these simple forms are normally adopted is the rather high price of form work and the severe climatic conditions which prohibit the use of very thin webs in I-shaped beams.

As an example of a slab bridge, fig. 1 shows a bridge over a Danish turnpike (continuous over 2x20 m with a thickness of 0,6m), and fig. 2 shows a typical Swedish bridge over a river, constructed as simply supported beam (span 30 m, depth 1,9 m). Another typical Scandinavian application is to combine a prestressed slab or girder structure with normally reinforced abutments to a frame construction, as illustrated by fig. 3, which shows a Danish road-bridge (clear span 36 m, depth in the middle 0,75m); this type of structure is especially suitable where the construction-height is limited.

Large bridges are rare in Scandinavia, but some outstanding bridges in prestressed concrete with main spans of about 100 m have been built, or are under construction in Sweden, using cantilever construction without scaffolding. Fig. 4 shows one of these bridges especially suited to the rather broad and deep Swedish rivers where a strong current and ice make the building of a scaffolding hazardous and costly.

Bridges made of prefabricated elements are — as mentioned above — rather rare. Small bridges (with spans from 5-12 m), are often constructed in Denmark with inversed T-shaped beams made in a long-line factory. Apart from this use prefabricated and post-tensioned beams have hitherto only been employed where special conditions have favored this procedure. A bridge with a single span of 34 m over a heavily used railway has been constructed in the suburbs of Copenhagen, where I-shaped beams are

Fig. 2 Simply supported beam bridge over Swedish river (30 m), cast in situ.

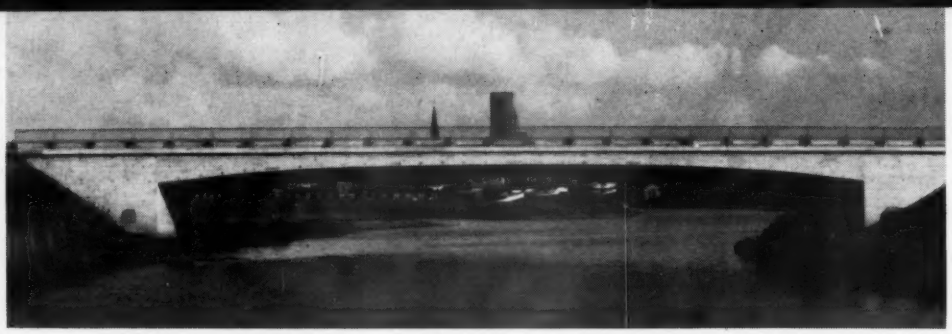


Fig. 3 Frame-bridge over Danish river (36 m) with prestressed superstructure fixed in reinforced abutments

assembled to a slab with a transversal prestressing. Fig. 5 shows another example, a part of the 500 m long approaches to Norway's largest bridge, where prefabrication of the main beams was advisable owing to the bad soil conditions which made scaffolding costly especially since the approaches rise to about 35 m over the ground level (spans 23 m, depth 2 m; the beams as well as the overlying slab were rendered continuous over about 8 spans by subsequent prestressing of the slab).

Fig. 4 Beam bridges over the Swedish river Tunsta (41 + 107 + 41 m) constructed by cantilevering without scaffolding.

B. Industrial and House-Building

Prestressed concrete has been used in this field especially for the roof construction of one story industrial buildings. In such structures large spans between the columns are very suitable, and prestressed concrete competes successfully with reinforced concrete under these conditions, and even with steel structures, as it is fireproof and demands much less maintenance. In Sweden, it is now almost the rule that roofings of this nature are constructed with beams of standardized type, produced in long-line factories. Fig. 6 shows a typical building of this type, and it should be mentioned that spans up to 25-30 m, made with prefabricated beams, are not a rarity. A similar development is taking place in Denmark, and has had a good start in Norway and Finland.

Post-tensioned members, too, are used for roof-structures, but to a lesser extent than pre-tensioned members, and especially where irregularities reduce the utility of the standardized pre-tensioned beams or where the spans are very large. An outstanding example is the roofbeams of a hangar in Helsinki Airport, with spans of 45 m, see fig. 7. The beams, which had the form of an arch-truss, were assembled from small prefabricated elements, using post-tensioning. Subsequently these 125 ton beams were lifted to their final position about 11 m over the pavement.

Prestressed multi-story buildings have not been constructed to any large extent in

Fig. 5 Approaches for steel arch bridge over the Norwegian river Glomma (22 x 23 m), with main beams prefabricated and mounted up to 35 m (60 t). Columns made with sliding shutters.

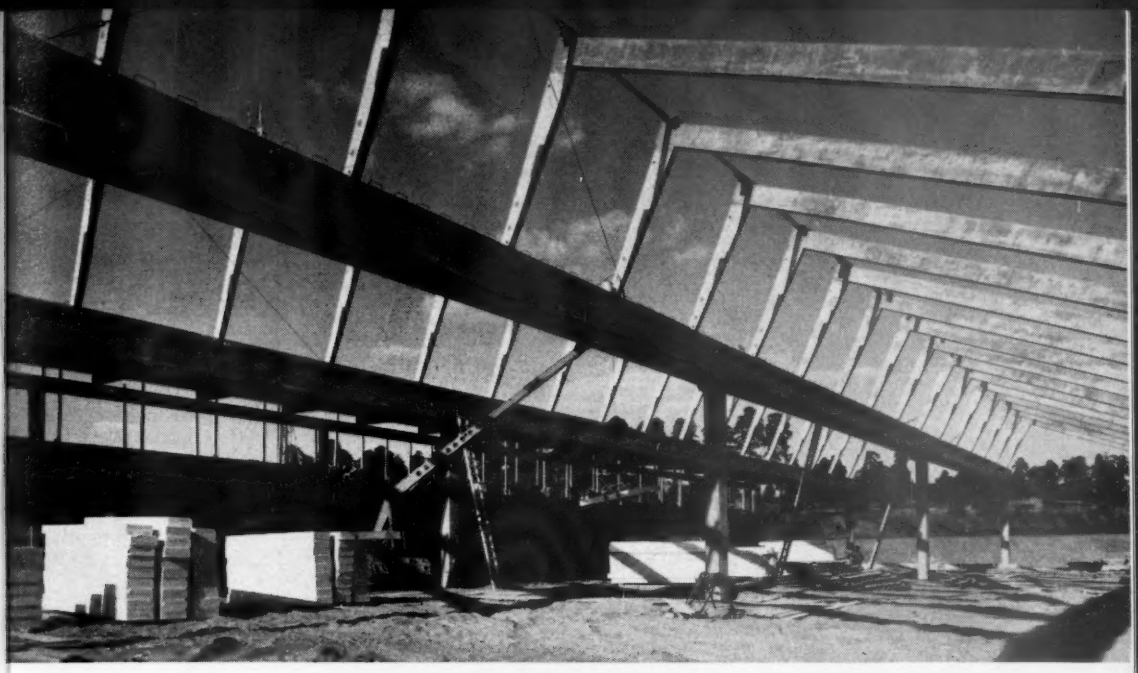


Fig. 6. Roof structure made with standardized prefabricated beams from long-line factory.

Scandinavia, but two interesting examples should be mentioned, a house building in Helsinki (fig. 8) and a factory building in Copenhagen (fig. 9). In both cases the prestressing was used to assemble rather heavy units (prefabricated outside the building site) to a rigid building frame, thus speeding up the construction on the limited area of the building site.

Prestressed shells have been used mainly in the form of spherical domes, comprising a prestressing of the edge beam for reservoirs and the like. Fig. 10 shows one of the biggest prestressed domes, covering a water reservoir in Stockholm (diameter 44 m, thickness 0,10 m).

Finally it should be mentioned that post-tensioned structures are not infrequently used to overcome a special problem in more conventional buildings erected in reinforced concrete. When such buildings are erected in city areas, a demand for large clear spans in the lower stories often arise in order to accommodate a service-station, a cinema or a department store. Prestressed concrete is in such cases a very powerful means of overcoming some difficulties since prestressing makes it possible to control the deformations of the beams and structures so that they can be kept within limits that will not damage the overlying structures. As an example, a garage can be mentioned in Stockholm where 20 m beams over the ground level carry several overlying stories bearing a heavy load (inter alia trams). The 30 beams necessary for this job were 1,8 m deep and 1,2 m wide.

C. Reservoirs and Silos

Concerning circular-cylindrical reservoirs and silos in prestressed concrete, Scandinavia has probably been leading in Europe; at any rate, the largest European water tanks, water reservoirs, cement silos, sugar silos and oil tanks of this type are to be found in Scandinavia, and other structures such as cement slurry basins, hot water tanks, etc. have so far only been constructed in Scandinavia.

All these structures have been prestressed with cables embedded in the wall, as the wire-winding systems are not favored in Scandinavia. This is due to the severe climatic conditions, which may injure the non-prestressed mortar protection of the wire-wound reservoirs, this being subjected to tensile stresses when the reservoir is full. Considerations of the same nature originating in the desire to lower the maintenance costs

Fig. 7 Arch truss beams (45 m) covering hangar in Helsinki Airport, assembled in units on the ground and mounted 11 m (125 t).

have led to the avoidance of all moving joints between walls and footings, although this demands more skill of the designer, the contractor and the supervisor.

Moreover it should be mentioned that the procedure of sliding shutters has been combined with the procedure of prestressing with perfect success. Some of the most outstanding examples may be briefly considered.

Fig. 10. shows the interior of one of two water reservoirs in Stockholm, each holding 17,500 m³ (diameter 44 m, water depth 11,5 m, wall thickness 0,25 m).

Fig. 11 shows a water-tower in Sweden, holding 8,500 m³. It should be mentioned that the conical reservoir with a diameter of 50 m and weighing about 2,500 t. was cast at ground level and later mounted 40 m with hydraulic jacks.

Fig. 12 shows a silo plant for cement in Copenhagen comprising 5 silos, each holding 4,000 t. cement (diameter 13 m, height 25 m, wall thickness 0,20 m).

Fig. 13 shows two Swedish sugar silos, each holding 20,000 t. of white sugar (diameter 35 m, height 29 m, wall thickness 0,30 m). In addition 7 silos, with a total content of 60,000 t. white sugar have been constructed in Denmark.

Fig. 14 shows a Norwegian 7,000 m3, tank for heavy oil.

As a special example of reservoirs should be noted swimming-pools, several of which have been constructed in prestressed concrete in Scandinavia. Fig. 15 shows the two swimming-pools, 50 m long and 20 and 17 m wide of an open-air bath in Oslo; each of the pools was entirely prestressed.

D. Miscellaneous Constructions

Outside the main fields of structural activities prestressed concrete has occasionally been used in Scandinavia for a fairly large number of other constructions. Without exhausting the list the following may be men-

Fig. 8 Prefabricated multi-story building in Helsinki (accommodating a University institute), assembled with prestressing of post- and pre-tensioned units.

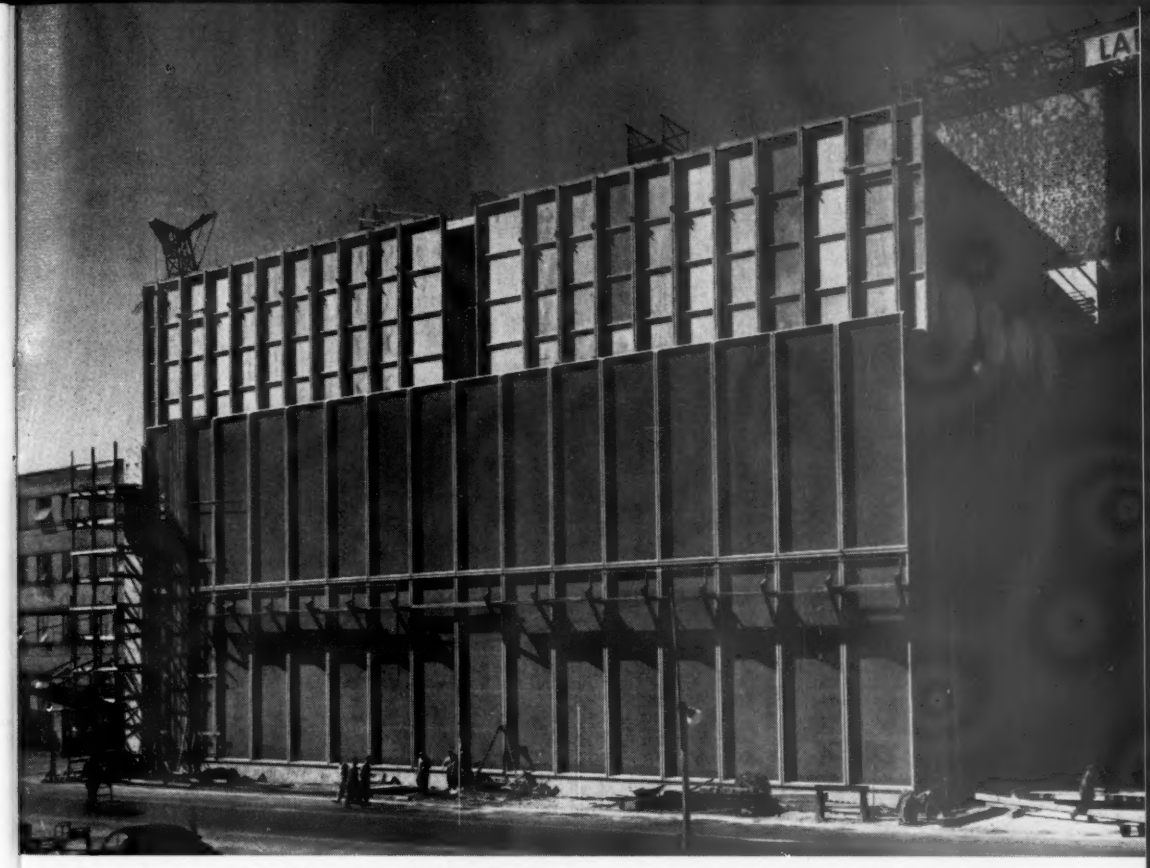


Fig. 9 Prefabricated multi-story building in Copenhagen (accommodating brewery cold storage tanks), assembled with prestressing of heavy, reinforced units.

tioned: special foundations (Norway and Sweden), water-tight chambers for hydro-electric plants (Norway), roofing over tunnels passing under existing buildings (fig. 16 shows an example from Stockholm), widening of existing bridges (Sweden and Denmark), grand-stands for sports-stadiums (especially in Denmark, see fig. 17) etc.

The record of prestressed activity would be incomplete without mentioning the comprehensive series of smaller elements which leave the long-line factories, comprising piles, poles, posts, joists, roof-slabs, frames for windows, safety-railing for highways, etc. Especially the Swedish production of prestressed tubes should be noted; they are made monolithically in one operation.

3. Scandinavian Trends in Prestressed Concrete

As may be gathered from what has been said, there is a trend towards simplicity in the Scandinavian use of prestressed concrete. A meticulous saving of materials is often sacrificed in order to achieve this simplicity, the two main reasons for this being the following:

a) the rather severe climatic conditions in the Scandinavian countries make conditions on the building-site rather difficult and prohibit the use of too thin and slender outdoor structures.

b) wages are rather high as compared to the cost of materials (thus resembling the conditions in the U.S.A.)

Thus solid slabs and beams of rectangular section are normally favoured instead of I-shaped beams and the like, and where continuous structures are concerned a solution is sought by means of cables running from one end of the structure to the other rather than a steel saving design with intermediate anchoring of the cables.

Another Scandinavian characteristic is a certain boldness in trying out prestressing on new types of structures in order to investigate its advantages and limitations.

Fig. 10 Reservoir in Stockholm, holding 17,500 m^3 water (diameter 44 m), with spherical dome-roof (0,10 m).

Fig. 11 Water-tower in Sweden, holding 8,500 m^3. Reservoir (2,500 t) was mounted on top of central tower (40 m) with hydraulic jacks after completion on ground.

The prestressing systems, hitherto used in Scandinavia are rather limited in number (as compared, for example, with Germany). The Freyssinet system was the first to be used, and is still the most general. Systems using bars, such as Dywidag, are increasing in use, and a special Scandinavian type has been developed (using rods produced in Sweden). The BBRV system has started rather successfully (especially in Sweden) and also the Gifford-Udall system. Finally, it should be mentioned that the Magnel system was used some years ago in Finland and that the Leonhardt-Bauer system has been used on one occasion in Norway. Fortunately most of the systems have been put on the market through firms independent of the contractors, so that free competition has been the rule.

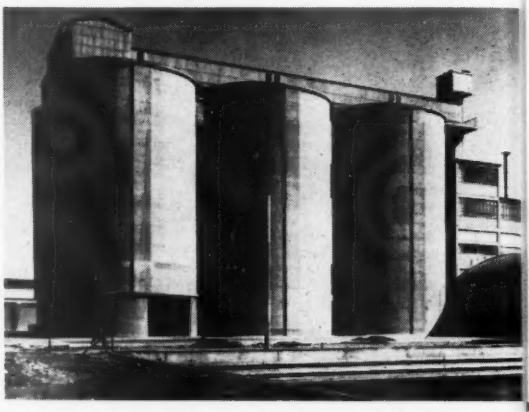


Fig. 12 Cement silos in Copenhagen, holding 5 x 4,000 t (diameter 13 m, height 25m) constructed with sliding shutters.

Original research work in Scandinavia on prestressed concrete has been confined to filling the gaps in the information obtained from abroad. The temptation of re-doing all the basic experiments has been avoided.

Research work has notably been done, and is still going on, concerning a problem of major interest for the Scandinavian countries: the effect of freezing on prestressed structures, especially the freezing of water or grout in the cable ducts. Means have been found to avoid the harmful effects of freezing, but research work is still going on to find a freeze-proof grouting mix. Other tests have been related to friction

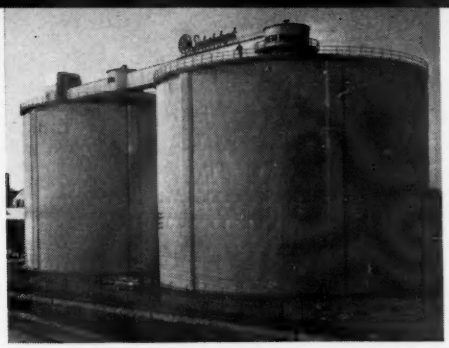


Fig. 13 Sugar silos in Sweden, holding 2 x 20,000 t (diameter 35 m, height 29 m).

Fig. 14 Norwegian 7,000 m^3 tank for heavy oil.

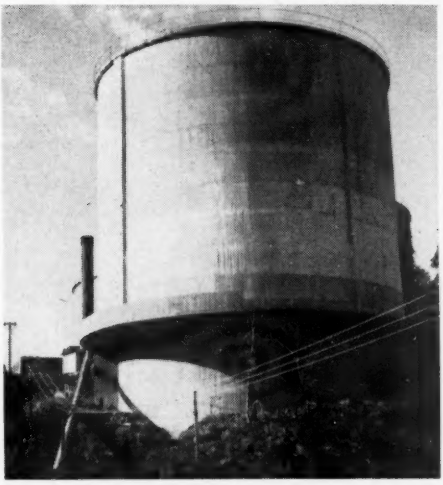


Fig. 16 Roofing for railway tunnel in Stockholm under existing building, constructed without moving the inhabitants (12 x 40 m).

Fig. 15 Swimming pools in Oslo, 20 x 50 m and 17 by 50 m

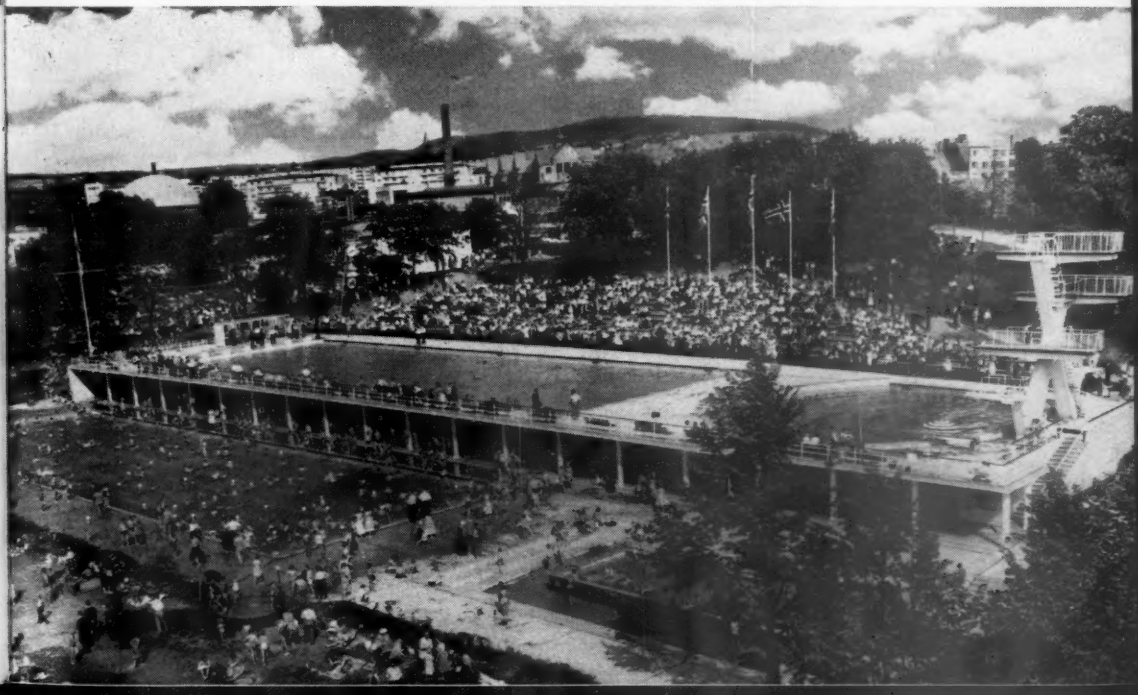
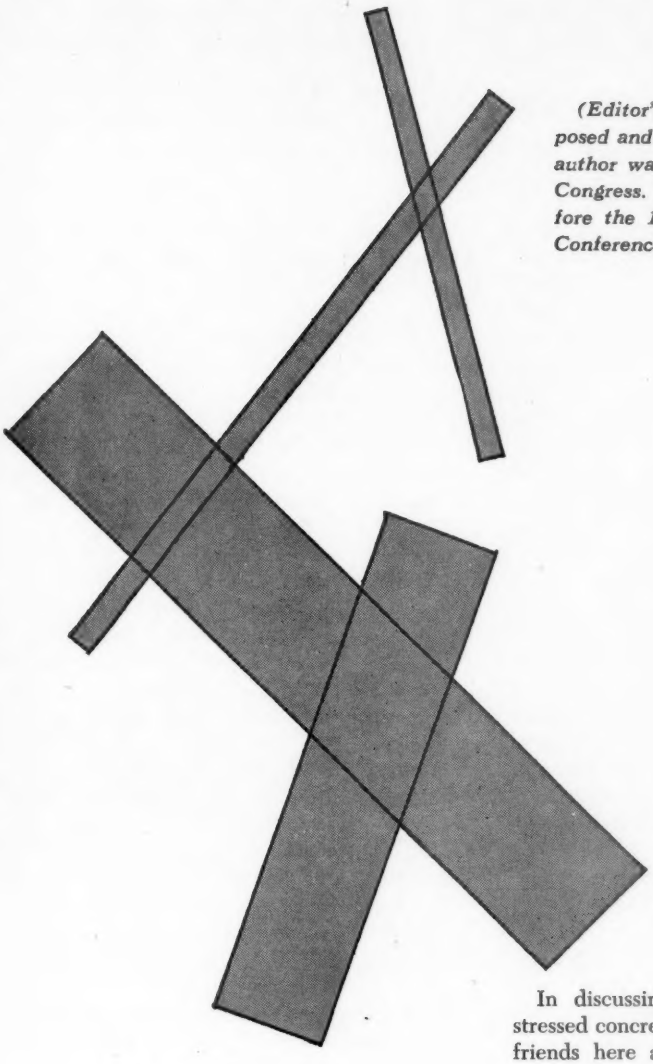


Fig. 17 Grand-stand at sport-stadium in Denmark, constructed with prefabricated U-shaped beams (12 x 95m).

in cables, resistance to fire and ultimate dynamic strength.

Congresses, with the aim of spreading knowledge of prestressed concrete, have been arranged by the Danish Society of Civil Engineers in Copenhagen in 1950 and by the Swedish Society of Civil Engineers in Stockholm in 1952. Engineers interested in prestressed concrete have formed associations in each of the Scandinavian countries, adhering to the International Federation of Prestressed Concrete. These associations have formed groups, which are carrying out further research and studies. Thus the Danish Society of Civil Engineers has formed a committee with a budget of 100,000 crowns for tests and research work on prestressed concrete.

Preliminary specifications for prestressed concrete have so far only been published in Norway. The general opinion in Scandinavia tends to consider it advisable to wait as long as possible with final norms, in order not to hinder the full development of prestressed concrete.



(Editor's Note: This paper was composed and delivered in Berlin while the author was attending the recent F.I.P. Congress. Delivered as an address before the 1,200 delegates to the Berlin Conference.)

DEVELOPMENT OF PRESTRESSED CONCRETE IN THE UNITED STATES

BY R. M. DUBOIS
Freyssinet Company, New York, N. Y.

In discussing the development of prestressed concrete with many of my European friends here at this Congress, it occurred to me that it would be interesting to give you a few words about the prestressing industry in the United States in relation to Europe, and the contributing causes which have influenced its growth during the past

ten years. This bird's eye view may be of at least some value to those of you who have no conception of the United States' engineering and construction industry, and to those of you who do, I beg your indulgence.

The first application of prestressed concrete was in circular tanks and reservoirs during the world steel shortage fifteen years ago. It was confined to these structures because mechanized methods had been developed which were still unknown to the United States in the field of linear prestressing. It was not until the free exchange of engineering design knowledge resumed with our friends in Europe that practical methods were introduced to our country. Even then the economy of prestressed concrete was not apparent to our engineers, and although we are known as a reasonably efficient nation, we were considerably less concerned with the efficient use of steel and concrete in our designs than most of you in other countries. It required five years of costly educational work among owners, engineers, architects and contractors to achieve for prestressed concrete a reasonable degree of acceptance. It may be added in passing that among those who received this technical assistance, was the American engineering firm who designed this magnificent Congress Hall.

Today one can say that prestressed concrete is used in the United States in as wide a variety of structures as in Europe with a few notable exceptions such as dams, floating caissons, and we have not yet begun any large scale production of railway ties, nor have we gone beyond the test stage in roads, runways and the like. If the variety of applications is similar to that of yours in Europe the proportion of one category of structures to another is perhaps not the same as with you. This point requires some further examination of the conditions which we find influence prestressed concrete applications in the United States.

Bridges undoubtedly account for the largest use of prestressed concrete measured by volume of concrete tonnage of prestressed steel. We are dealing in the U.S.A., however, with the engineers of 48 autonomous State Road Commissions, whose opinions on design and construction specifications vary as much as between any 48 sovereign nations, and their word is final for all practical purposes. This makes for great regional differences which our Central Federal Bureau of Public Roads can influence but not dictate to bring about national acceptance of design criteria or specifications. In addition, we have privately financed toll road and bridge authorities as well as the county and municipal administrations who are each quite independent. A further handicap to uniformity of design is the wide variety of terrain and climate, but in spite of this we have achieved a remarkable degree of standardization and acceptance of prestressing techniques. This has been brought about in large measure by the over two hundred permanently established manufacturing plants, which have a substantial capital investment, which can only be amortized by efficient production methods and a reasonable degree of standardization in the bridge members they produce. Our own Prestressed Concrete Institute has fostered this standardization as have the engineers who have designed the manufacturing facilities. Only in cast in situ bridge decks do we find real deviation from the standardized sections adopted by many State bridge engineers. In this field of cast in place bridges, particularly those which are continuous, we are far behind our friends in Europe. Unlike those of you on the continent, we rarely have the opportunity to work hand in hand with a construction firm to present a scheme to the owner as practically all public bid projects in the United States are fully designed to the last detail at the time the project is advertised for public tender. In very few cases is an alternative scheme permitted by the owner, and the contractor frequently has only ten days to price the job before the letting, which of course excludes a redesign or alternative design before the opening of the tenders. This frequently has the effect of confining the design to a conventional, unimaginative, standardized bridge with no consideration for a contractor's engineer to exercise ingenuity in both the scheme and its means of execution.

In other words, with our tendency toward standardization, our progress is rather like that of a ship convoy, it travels at the speed of the slowest ship and so our prestressed concrete engineers are held back by the ten knot speed of our less progressive element.

In the field of industrial buildings we have found, as you, a fertile area for prestressed concrete. In fact, the widely used double T slab section so common to almost

every U. S. prestressing plant provides the bread and butter to those who have long line prestressing benches. It is the key prestressed building material in Florida and other states where the climate and distance from the steel mills make for the greater acceptance of concrete structures. We witnessed a period two years ago, when structural steel was at a premium and deliveries were slow and uncertain. This contributed greatly to the sudden redesign in prestressed concrete of large structures such as the Boeing Aircraft Research and Development Center in Seattle, Washington, the IBM Electric Typewriter plant in Lexington, Kentucky, and many others, but today as most of you know the Detroit automobile industry is less of a customer to the steel mills and structural steel is again plentiful at very competitive prices. In spite of this, however, prestressed concrete maintains its place, because the construction industry is more familiar with the techniques, better able to estimate costs of prestressing, the material itself provides for more workers at the local level rather than in Pittsburgh, and the owner and his architect are finding they can achieve designs and quality heretofore unheard of.

Yes, we in the United States have brought down the costs of prestressing, and only the most mechanized methods survive in a field which is the most competitive in the entire construction industry, at least in my opinion.

There are only to the best of my knowledge about seven post tensioning methods used in the United States, four of which are parallel wire systems, two alloy bar methods and one purely American-developed standard cable method available from the two major producers of high tensile steel. In the case of the other six systems they are all of European inspiration with varying degrees of modification by their American owners or licensees.

Pretensioning has had the most spectacular development in the United States. It began with major projects in which a million dollars in value of precast slabs, stringers and piles would justify the initial investment in a casting bench and permit the amortization of the installation on a single project. Later, pretensioning methods were adopted by concrete building material manufacturers and ready-mix plants as an adjunct to their existing business. As the market for prestressed precast members increased, many entered this field as regional suppliers to the building and bridge contractors. Messrs. Price, Gerwick and Smith have thoroughly covered the subject in their respective Session III papers. Permit me to emphasize, however, that in the United States we use no smooth or deformed wire in prestensioning — we have adopted exclusively the 5/16, 3/8 or 7/16 inch dia. strand. Furthermore, we have developed various systems of deflecting or depressing strands in a draped pattern which permits the pretensioning of heavy bridge girders in the range of 70 to 120 ft. which was formerly confined to post-tensioning methods.

The economy of this procedure, compared with post-tensioning or a combination of pre- and post-tensioning, is still controversial as costs will vary widely with the type of installation in each case. We agree with Mr. Gerwick, however, that there is an increasing trend toward precasting with deflected strands.

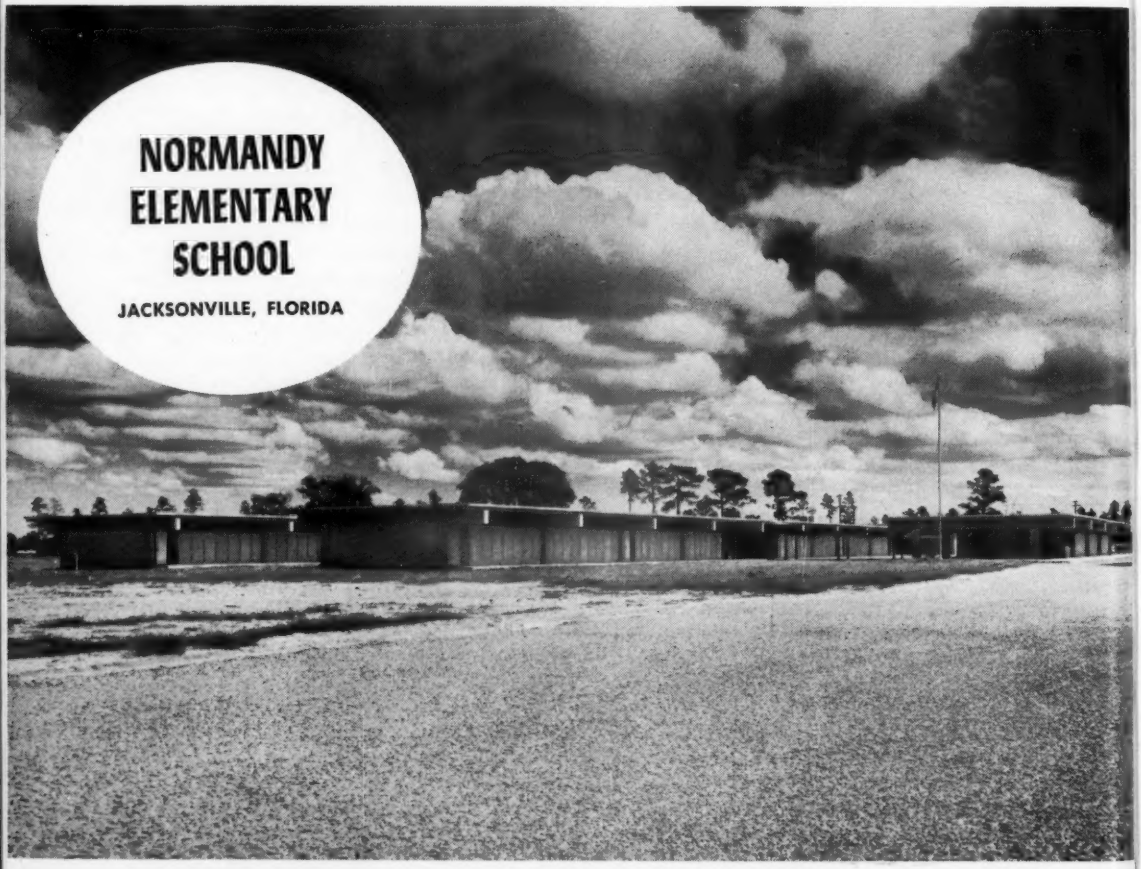
The size and cost of our pretensioning installations range from 4 million dollars to small producers whose pretensioning facilities have cost somewhat under 100 thousand dollars. These 200 or more manufacturers represent the largest single customer for the pre-stressing steel producers, and it is for these plants that our research and development are primarily directed today. It is they who set the pace in the quality control of prestressed concrete, and the general contractor who does cast in place post-tensioning must follow their high standards and mechanized methods to compete in bridge and building works. In fact, because of the ratio of plant labor cost versus field labor which can be frequently greater than 1 to 2 the job site mechanization is extremely important in all post-tensioning systems. Labor costs in the United States vary considerably by geographical areas, and the type of labor imposed upon the contractor by the labor organizations. In New York City the iron workers handle all steel placing and jacking operations, and their rate of pay is fixed at a rate approximately four times that of labor performing a similar task 300 miles away.

These, gentlemen, are some of the characteristics which have greatly influenced the trend of prestressing in the United States, where last year it was estimated to have grown to a 400 million dollar industry.

HARRY BURNS, AIA

GEORGE FISHER, AIA

(Note: At a regional conference of the American Institute of Architects held at Sarasota, Florida on April 17 and 18, only one school building was recognized for an award among various types of buildings representing exhibits from four states, North Carolina, South Carolina, Georgia and Florida. And that school was built of prestressed concrete! The winning architects were Harry E. Burns, Jr., AIA and George Fisher, AIA of Jacksonville, Florida. This paper which accompanied their exhibit is a fine example of a design combining form function and economy. It it also an interesting study for architects, engineers, school boards and prestressing producers on how to plan a school building to get the most and the best for the least expenditure.)



Among the many strict requirements programmed for this elementary school in Duval County, Florida, none was more rigid than economy of construction. The problem, stated briefly, was to produce an elementary school which must

a) have 16 classrooms capable of accommodating up to 37 pupils per room, and which must be readily expandable to 24 classrooms;
b) include an administrative suit with general and principal's offices, teachers' lounge, health clinic, library and work rooms;
c) provide a cafetorium, including a stage, and complete with kitchen equipment.
d) be fireproof;
e) be easy and inexpensive to maintain;
f) meet a building budget of $320,000.

The site was relatively flat, with its southwest property line fronting the only street.

The planning solution was a simple and direct employment of the conventional finger plan, which capitalized on Florida's climate in permitting outdoor corridors and classrooms, provided bilateral, non-glare lighting, and made expansion a simple matter of building another wing, and, like them, reached via a covered walkway.

To be economical, the structural system had to be consistent and modular. If the building was to be fireproof, concrete was the structural material dictated. Consequently a system of concrete bents all identical and all 30' on center served to define the classrooms and to support the roof. The bottoms of these bents were set at the legal minimum of 7', keeping the outdoor corridors in scale with its small users. Set atop these bents and spanning between them were prestressed, precast concrete double-tee beams, the bottoms of which were left exposed over the outdoor corridors, and covered with acoustical tile inside the building. It is interesting to note that the more than 39,000 square feet of roof deck was set in place and ready to receive roofing in a matter of two days.

Between classrooms, framed by the concrete bents, structural glazed tile is employed. This theme is repeated in the toilets, the kitchens and cafetorium. The exterior walls, between bents, are of curtain wall construction, with porcelain enamel on the outside, and either chalk board, cork board, or cement asbestos on the inside.

Unit convectors, employing hot water, are used to heat the building and to provide mechanical ventilation.

There is no plaster anywhere in the building. The only surfaces receiving paint are the concrete bents, the doors and cabinets.

The school is approximately 35,360 square feet in area, and contains some 300,000 cubic feet. At the contract price of $297,000, the cost per square foot obtained was $8.40. This figure, together with the fireproof and maintenance-free character of the building, so pleased the School Board, that they have seen fit to build it, with slight modifications, on four different but similar sites.

To the Editor:

There is presented for your consideration a Proposal of Supplementary Sections of Prestressed Concrete Beams for Highway Bridges of Composite Construction.

For the last several years the advance in the field of prestressed concrete bridges in the United States has been remarkable. It is well established now that this rather new type of construction will contribute efficiently and satisfactorily toward the completion of the gigantic Federal and State highway programs. To expedite design as well as fabrication, the importance of standardization cannot be over-smphasized.

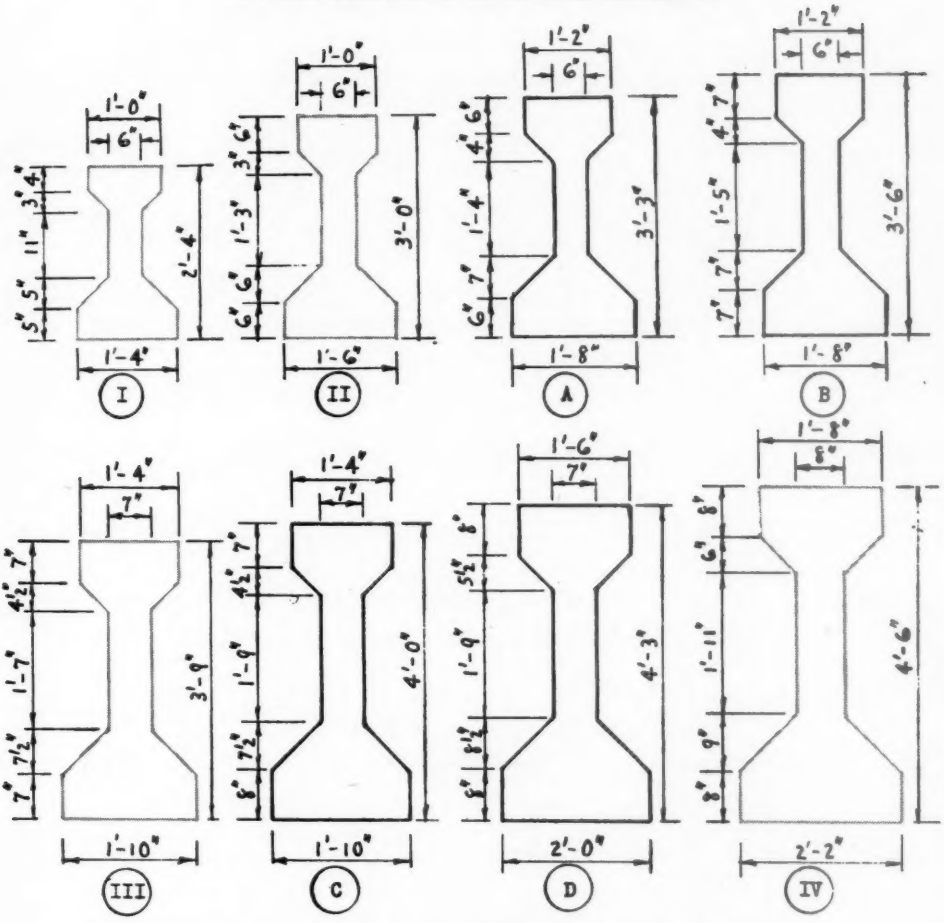
The Joint Subcommittee of AASHO and PCI on Prestressed Concrete Bridges ought to be highly praised for its effect to have established the four (4) Standard Sections. These Sections are noticed to be well proportioned, with the simplicity for forming, the ease for placing concrete, and the adequate structural capacity, free from any sharp reentrant angles or other noticeable construction objections. With proper variation of the amount of steel and of the spacing between beams, these four Standard Sections offer a sufficient choice, structurally, for any span up to 100 ft. or more. However, the maximum economy of material cannot be achieved for all loading and geometrical conditions. This may be indicated by the large increment of 9" in depth from 3'-0" for Type II to 3'-9" for Type III, and from 3'-9" for Type III to 4'-6" for Type IV. It is true that the possible savings in the quantity of concrete alone may be easily offset by the cost of fabricating additional formwork of various dimensions, but it still remains as one of the major factors in determining the total cost of any given job. It becomes even more important, should the layout of beams be dominated by the clearance requirements. Quite often, a reduction of only a few inches in the construction height may suffice to result in a considerable amount of savings in the alignment. Therefore, a supplement of Sections resulting in smaller increments of depth seems to be in order and desirable.

The writer herein proposes another four (4) Sections of prestressed concrete beams for highway bridges of composite construction, supplementary to the already established four Standard Sections as recommended by the Joint Subcommittee. It is believed that adopting these proposed Sections would enable a designer to have a much broader selection of prestressed concrete beams, and achieve a better economy in material, possibly in the total cost as well.

Dimensions and properties of all Sections are shown on the following pages.

Kenneth Diao
Structural Engineer
Madigan-Hyland, New York

DIMENSIONS OF VARIOUS TYPES OF P/C BEAMS



Notes: Types I, II, III, and IV are the Standard Sections as recommended by the Joint AASHO-PCI Subcommittee.

Types A, B, C, and D are the proposed Supplementary Sections.

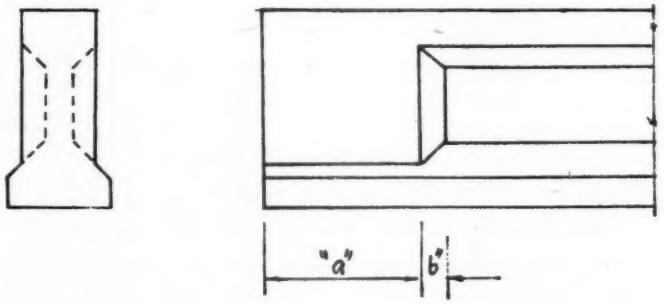
(3)

PROPERTIES OF VARIOUS TYPES OF P/C BEAMS

Type	Depth of Beam	Cross Area	Unit Weight	Moment of Inertia	Top Section Modulus	Bottom Section Modulus	End Block		
							Gross A	"a"	"b"
	Ins.	Sq.in.	Lbs/ft	$(in)^4$	$(in)^3$	$(in)^3$	Sq.in.	Ft-in	Ft-in
I	28	276.0	288	22,700	1,480	1,810	360	2-0	6
II	36	369.0	385	51,000	2,530	3,220	477	2-0	6
A	39	431.0	449	72,500	3,340	4,190	591	2-6	9
B	42	471.0	491	91,600	3,930	4,910	639	3-0	9
III	45	559.5	583	125,400	5,070	6,190	771	3-6	9
C	48	595.5	621	151,100	5,680	7,070	825	4-0	1-0
D	51	683.5	712	201,600	7,230	8,720	975	4-0	1-0
IV	54	789.0	822	260,700	8,910	10,540	1,137	4-6	1-0

Notes: Types I, II, III, and IV are the Standard Sections as recommended by the Joint AASHO-PCI Subcommittee.

Types A, B, C, and D are the proposed Suplementary Sections.



(4)

APPLICATION FOR MEMBERSHIP IN THE PRESTRESSED CONCRETE INSTITUTE
(A non-profit corporation)

I am applying for membership in the classification checked:

☐ Active (producer). Membership Dues: $250.00 annually.
Engaged in the following types of prestressing:

_____Post-tensioning _____On-the-job post-tensioning
_____Pre-tensioning _____On-the-job pretensioning
_____Combination of both _____Precasting _____Design

☐ ASSOCIATE (related business). Membership dues: $250.00 annually.
I am in the business of:_____

_____

☐ PROFESSIONAL (registered architect or engineer). Membership Dues: $25.00 annually.
I hold Certificate No._____ of the State of_____

☐ AFFILIATE (technical and supervisory personnel). Membership dues $15.00 annually.

☐ JUNIOR (limited to architects and engineers in training). Membership Dues $15.00 annually.

☐ STUDENT (limited to students of accredited schools of architecture or engineering).
Name of School_____
Membership Dues: $10.00 annually. Outside continental U.S.A. including Canada: $12.00 annually.

NAME OF COMPANY APPLYING FOR ACTIVE ASSOCIATE MEMBERSHIP_____

_____

ADDRESS_____

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NAME OF REPRESENTATIVE IN INSTITUTE AFFAIRS_____

APPLICANTS FOR PROFESSIONAL, AFFILIATE, JUNIOR AND STUDENT MEMBERS PLEASE FILL IN BELOW:

NAME_____

ADDRESS_____

CITY_____ STATE_____

COMPANY AFFILIATION_____

POSITION_____

Date_____ Signature_____

Make no payment until application is approved. Dues will be prorated from April 1 for all classifications.

425 N. E. FIFTH STREET
BOCA RATON, FLORIDA

MEMBERSHIP QUALIFICATIONS

SCHEDULE OF DUES

Anyone engaged in the production of prestressed concrete, or in the production of materials or equipment allied to the prestressing industry; licensed architects and engineers; engineers and architects in training, and students enrolled in accredited schools of architecture and engineering, are invited to apply for membership in the Prestressed Concrete Institute. Membership classifications have been established as follows:

ACTIVE

Organizations and individuals actively engaged in the production of prestressed concrete products.
Annual Membership Dues **$250.00**

ASSOCIATE

Organizations and individuals engaged in the production of materials and equipment allied to the prestressed concrete industry.
Annual Membership Dues **$250.00**

PROFESSIONAL

Limited to registered architects and engineers.
Annual Membership Dues **$ 25.00**

AFFILIATE

Limited to supervisory and technical employees, non-graduate.
Annual Membership Dues **$ 15.00**

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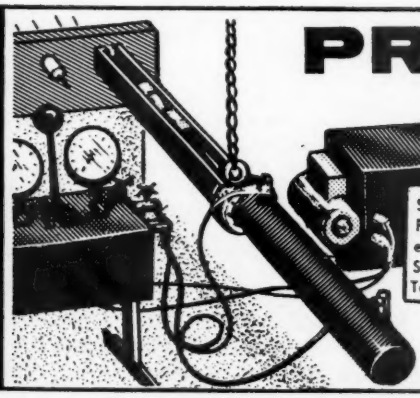

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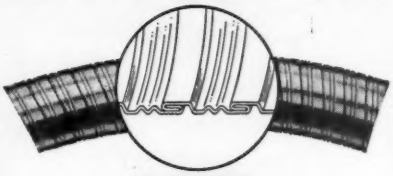

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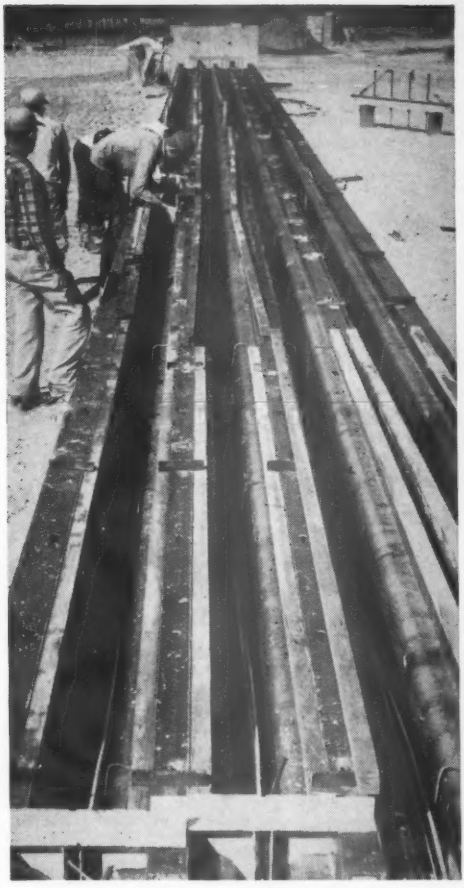

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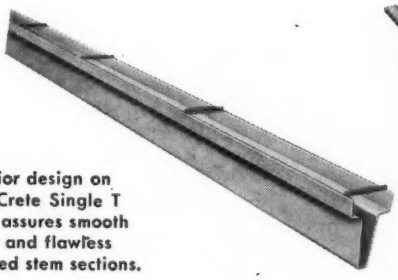

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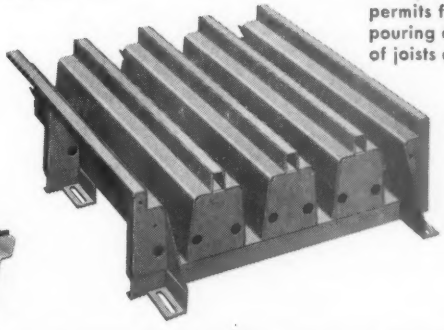

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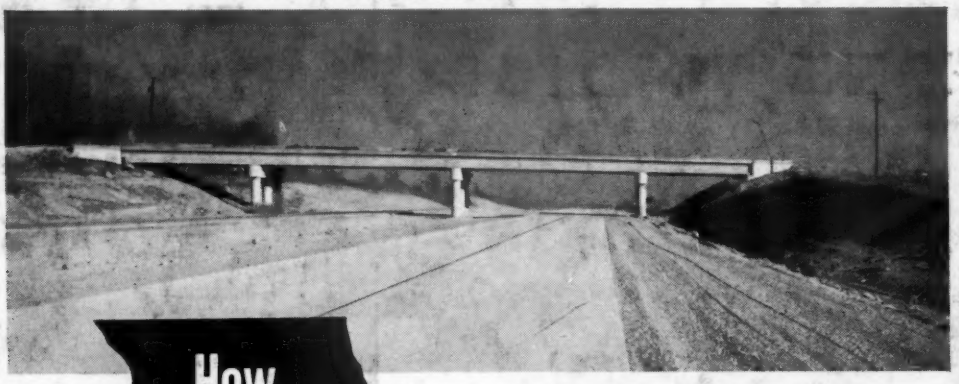
Typical finished prestressed concrete bridge on the Northern Illinois Toll Highway. Four companies are engaged in producing prestressed members for this project: Consumers Company, McCook, Ill.; Material Service Corporation, Algonquin, Ill.; Lewistown Midwest Division, American-Marietta Company, LaGrange, Ill.; and Midwest Prestressed Concrete Company, Rochelle, Ill.



. . . ILLINOIS TOLL HIGHWAY COMMISSION SETS AN IMPRESSIVE "PRESTRESSED" EXAMPLE

The following quotations are taken from a paper, "Prestressed Concrete Bridges for the Illinois Toll Highway," presented at the recent World Conference on Prestressed Concrete by M. E. Bender of Joseph H. Knoerle and Associates, Inc., Baltimore, Md., designers of the bridges.

"Of a total of 289 bridges on the entire project, the superstructures of 224 are carried wholly or in part by prestressed concrete stringers with varying spans up to 107 feet.

"Approximately 448,000 lineal feet of prestressed stringers were required . . .

"A little over 50,000 lineal feet of 36 in. diameter cylindrical prestressed concrete piles will be placed for piers in 90 structures.

". . . estimates of the entire project show that about 45,000 tons of structural steel members were replaced by prestressed concrete at a saving of approximately $4,000,000 over report estimates, and nearly $12,000,000 over steel at prevailing prices.

"Comparatively recent improvements in manufacturing . . . were factors in the selection of prestressed concrete members . . . Through these developments it has been possible to hold the cost of prestressed members at reasonable prices in spite of general rises in material prices."

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